Report

in support of a nomination for

Broken Hill Mines and Infrastructure

to be declared a

Centenary of Federation

NATIONAL ENGINEERING LANDMARK

Square set timber and fill in depleted Stope mid 1890's

Prepared by

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for the

Engineering Heritage Committee
Sydney Division
The Institution of Engineers, Australia

December, 2000

Commemorative Plaque Nomination Form

Date. ...20 December 2000

To:

Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

From ......Sydney Division
Engineering Heritage Committee

Nominating Body

The following work is nominated for a:-

- National Engineering Landmark *
- ~~Historic Engineering Marker~~ *

* (delete as appropriate)

Name of work........Broken Hill Mines and Infrastructure

Location, Including address and map grid reference if a fixed work...

.........Broken Hill NSW 2880

........Plaque location: Line of Lode Visitors Centre

Owner.............Broken Hill City Council

....

The owner has been advised of the nomination of the work and has indicated (attach a copy of letter if available) ....approval for Plaquing at a council meeting

....

Access to site ....Accessible to the public

....

Future care and maintenance of the work ....Broken Hill City Council

....

.Name of sponsor ....Line of Lode Association...

For a NEL, is an information plaque required? ....Yes...

....

Chairperson of Division Heritage Committee/Panel

Additional Supporting Information

Name of work ....Broken Hill Mines and Infrastructure..................

Year of construction or manufacture.......... This citation -1885 to 1912............................

Period of operation ....1885 to 2001

Physical condition................Some remnants of early mining work and infrastructure exist along with more modern mine buildings along the Line of Lode. Also, a number of important associated buildings remain.

Engineering Heritage Significance:-

Environmental Engineering

1. World first placement of tailings underground sometime between 1901 & 1905 Sulphide Corporation

Mining Engineering

1. Introduction into Australia of "square set " timber roof support
2. World first use of mullock for roof support (BHP)
3. World first development of cut and fill mining techniques (BHP & Sulphide Corp. mines)
4. First Australian use of electric lighting and electric tramways underground (BHP mine)
5. Australia's first all electric mine (BHP Block 10 Co.)

Metallurgical Engineering

1. World's first large scale recovery of zinc sulphide concentrates (Sulphide Corp)
2. World first development of flotation (G Delprat & BHP)
3. World first development of selective flotation (L Bradfield & BHP)

Infrastructure

1. In 1888, Broken Hill was connected to the South Australian ports of Adelaide and Port Pirie by Australia's and possibly the worlds most profitable (based on return on equity) rail company –The Silverton Tramway Company.
2. In 1889, gas and electricity were supplied to public customers by private companies.
3. In 1890, one of the earliest examples of a BOOT (build, own, operate, transfer) contact for water supply was commenced by the Broken Hill Water Supply Ltd

Technological / scientific value... *Extreme*

Broken Hill was the centre of Australia's first large scale mining. The techniques developed made Australia a world leader in mining technology.

Professor G Blainey in *The Rush that Never Ended* states "In the last thousand years in metallurgy it (***flotation process***) stands with the cyanide process (*for gold recovery*), and the Bessemer process (*for steel making*), as one of the three great advances."

The development of selective flotation quickly spread to the copper mining operations around the world.

Historical value........ *Extreme* -Possibly of world heritage significance

The line of Lode comprising 500Ha of original Mining leases has been entered in the Register of the National Estate

Social value..............*Very High* -Has tremendous tourist potential and is being developed for this by a Federal Government Centenary of Federation grant of $4.5M

Landscape or townscape value.........*Very High*...

Rarity ....*Extreme* -In Australia only Kalgoorlie may rival Broken Hill in size and scope as a mining city. However, Broken Hill was a pioneer that exported mining and metallurgical technology not only to Australia but the rest of the world.

Representativeness..................*Very High*...

Contribution to the nation or region...*Extreme* -During the period 1885-1912 Broken Hill made a significant contribution to Australia's GDP and helped make Australia the wealthiest country in the world per capita

Contribution to engineering........*Very High*

Persons associated with the work ....Outstanding amongst numerous engineers Leslie Bradford, Guillaume Delprat, Sir Herbert Gepp, James Hebbard, Zebina Lane, William H Patton, H H Schlapp, W E Wainwright, Captain John Warren

Integrity.... ....*Moderate*...

Authenticity............*Extreme* - Documented evidence, particularly the book "The History of Broken Hill" Leonard Samuel Curtis, 1908 Frearson's Printing House SA

Comparable works (a) in Australia.................none...

(b) overseas... .... none known

Statement of significance (its location in the supporting documentation)............................

"Clearly of World Heritage Significance" -G J Drew

"The resultant development of the flotation process at Broken Hill is one of the most important inventions of the 20th century" –I A Mumme

Citation (70 words is optimum)

Broken Hill Mines and Infrastructure

Around the turn of the century Broken Hill led the world in mining and minerals processing technology. The development of flotation has been described as one of the outstanding achievements of twentieth century technology. Broken Hill made huge contributions to the wealth, welfare and social structure of Australia. Its engineering heritage apart from its significant achievements is notable for lack of government involvement.

Proposed location of plaque ....Line of Lode Museum..................................

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Introduction

Broken Hill is Australia's longest lived mining city. Its massive orebody has proved to be the world's largest silver-lead-zinc mineral deposit (Drew G J 1991 p4). Mining began in 1885 and will continue to 2006. The developments over the first 25 years, which spanned the turn of the century and federation, had major effects on the population, the economy and politics of Australia. Blainey G. 1963 p272 states "On the eve of World War 1 Broken Hill had over 35,000 people. Man for man it was Australia's most productive city." It had created more wealth than any other mining town and also spawned Port Pirie, which was the second largest town in South Australia.

While the mineral deposit was large and rich, there were forbidding problems. Broken Hill was located far in land without infrastructure in a dry and hot country. The upper oxidised ore of the deposit was complexly folded, friable and unstable. Heavy timbering underground caused fire hazards. The deeper sulphide ore being mined at the turn of the century was difficult to concentrate so large amounts of lead, some 50% of silver plus most of the zinc was being added to large dumps of tailings.

The ingenuity and enterprise of the engineers and managers at the mining companies and supporting companies in overcoming these problems caused Broken Hill to be great. The cover of Blainey G. 1968 states "Broken Hill developed into one of the most interesting laboratories in the history of metallurgy". Out of this came the flotation process described by Mumme I A, 1993 p347 as "- one of the most important inventions of the 20th century" and by Lynch A J, 1992 p15 "- as one of the greatest contributions that Australia made to industrial technology" In parallel with the developments in metallurgy there were innovations in mining technology. The concept of placing of tailings underground as an integral part of mining (cut and fill) was a world first development around the turn of the century. Forty years later a simple improvement on this idea, the concept of hydraulic stowing or filling, developed at Broken Hill, caused a major step forward in mining productivity and underground safety around the world.
Lynch A J, 1992 p15 states "Fifty years after the success with flotation Broken Hill metallurgists were again in the forefront of science and technology in mineral processing."

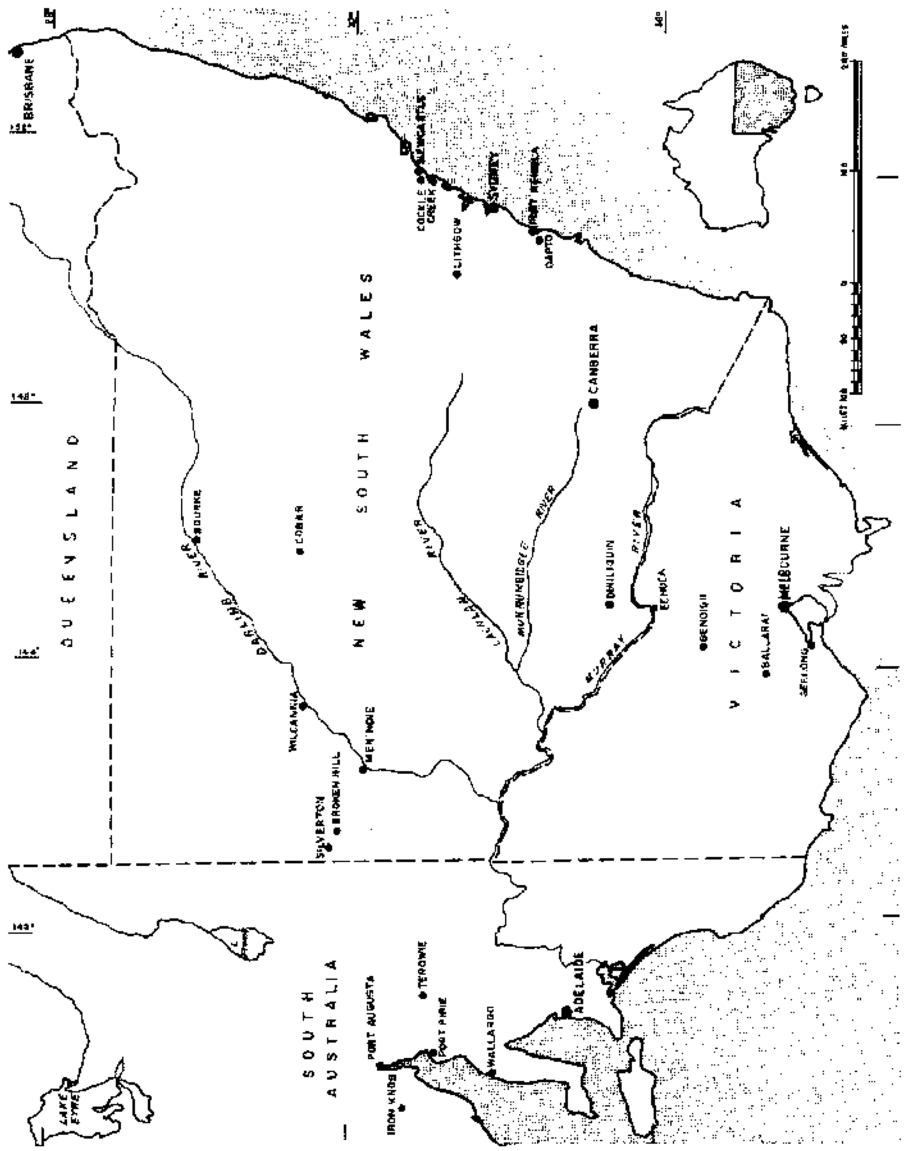
This report is concerned with engineering features and innovations around the turn of the century and federation. Maybe in future subsequent events will be cited for their engineering heritage value.

Location

Broken Hill is located approximately at latitude 32S and longitude 142E in western NSW some 45km east of the South Australian border and 250km north of the Murray. In a direct line it is nearly 1000km from the NSW administrative centre of Sydney, 750km from Melbourne (Victoria) but only about 300km from Adelaide (South Australia). See Figure 1.

Mining, for silver, originally started at Thackaringa (1877) 32km south west and at Silverton (1882) 21 km north west of Broken Hill. The South Australian Government in 1885 built a railway from Peterborough (68 km from Port Pirie) to Cockburn on the NSW border (about 270 km). This was extended in 1886 by a private company to Silverton and later in Jan 1888 to Broken Hill (Curtis L S, 1908).

Figure 1
Broken Hill Location



Orebody and Mines

The orebody is now thought to be of sedimentary origin in a shallow marine environment associated with volcanic exhalation. The orebody and surrounds were uplifted, folded and metamorphosed by later volcanic activity (Mackenzie D H, 1992 p187).

Figure 2A

Longitudinal section of the Broken Hill orebody.

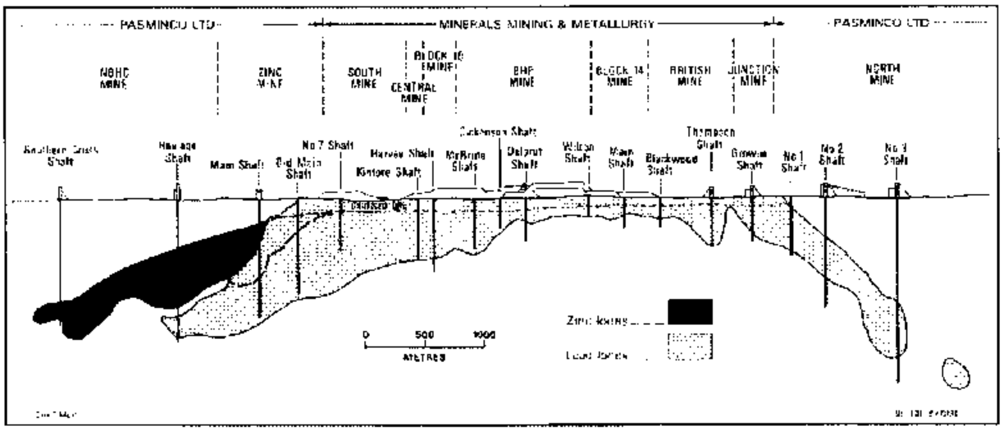


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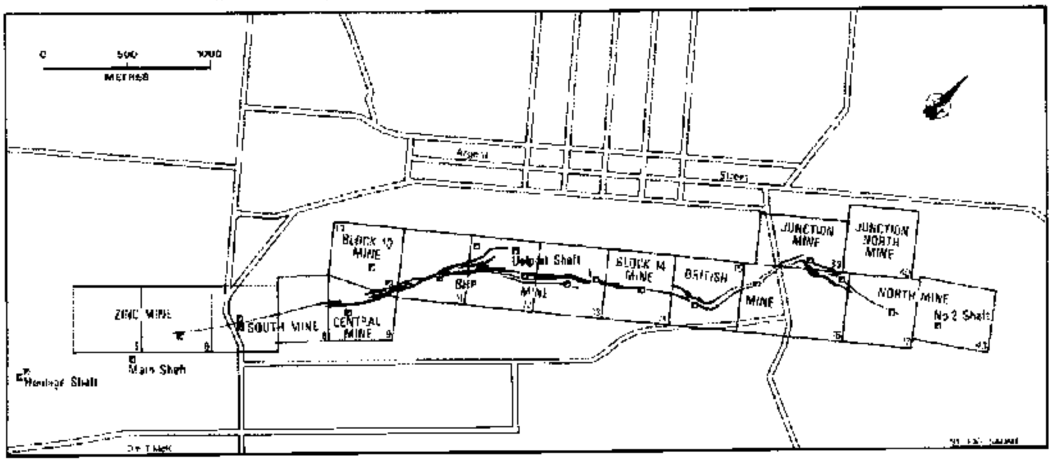
Figure 2 B

The line of lode prior to removal by mining.
Also shown are the original mining leases (1885) and principal mines.



The lode (Figure 2A), shaped like a boomerang standing on its ends, is 7.5 km long, upto 850m in vertical extent and 250m wide. It outcropped in the centre as *the broken hill* and plunges to more than 1.6 km at the northern end (Drew G J. 1991 p12). The BHP (Broken Hill Propriety Ltd) syndicate initially pegged all the centre part of the lode (7 leases) at the end of 1883. Towards the end of 1884 silver chlorides were noticed at the bottom of a shaft sunk by the syndicate.

A public company was floated as BHP in Aug 1885 to takeover and develop the mine. The company floated off the end parts of the leases into separate companies – The "British" Broken Hill Pty Ltd (blocks 15 & 16) and The Broken Hill "Block 14" Co. Ltd in 1887 and The Broken Hill Block 10 Co. Ltd in 1888 (Curtis L S, 1908 pp8-11). The mines on the lode are shown in Figure 2B. The BHP mine closed in 1939. The Central mine (block 9) became Sulphide Corporation in 1895. Zinc Corporation was formed in 1905 to treat tailings purchased from other mines. In 1911 it acquired the Broken Hill South Blocks (blocks 5, 6, 87 & 88) Ltd which had leases at the southern end of the lode next to the South Mine (blocks7 & 8). The Zinc Corporation was a founding company of the diversified miner CRA (now Rio Tinto) (Drew G J, 1991 pp6-11).

Only one company, Pasminco, remains extracting ore from the extreme north and south ends of the lode.

Mining and Processing

Early mining and processing of the weathered oxidised upper layer of the orebody used the techniques developed at the Burra and Moonta (South Australia) copper mines in the period 1845 to the mid 1870's. The mining technique involved heavily timbered shafts and drives leaving behind a large portion of the orebody in pillars (for roof support) and floors of extraction levels. The large width, depth, continuity and friable nature of the orebody required new mining methods. Already in 1886 BHP were using waste rock for working floors in "overhand stoping" (Curtis L S, 1908 p38). The increased use of waste as fill was an important Broken Hill initiative.

The initial oxidised ore mined was rich in silver and lead, and was smelted direct. BHP erected the first smelters at Broken Hill in 1886 (Drew G J, 1991 p14). As mining went deeper the mineralisation became more sulphide in composition. Also, the zinc content increased. Both the sulphide and the zinc caused smelting problems. BHP installed a gravity concentration plant in 1888 to separate the heavier lead-silver minerals from the zinc minerals and waste rock. In this the rate of upward or across flowing water is adjusted to remove the lighter materials. The ore, however, was an intimate mixture of minerals. Crushing and grinding was required to release the separate minerals but grinding too fine meant gravity alone was no longer effective. Various mines developed innovative plant to maximise the recovery of the valuable lead and silver. Much of the zinc and some 50% of the silver and much lead were put out on tailings dumps.

The development of the flotation process to treat tailings from 1902 revolutionised minerals processing. Flotation utilises differences in the surface properties of various minerals. The surfaces of some minerals such as metal sulphides to an extent are water repellent or hydrophobic. When bubbles are created in a water mix the metal sulphides prefer to adhere to the bubbles, which can be collected as froth from the surface of the water. Added chemicals can change surface properties and enhance froth formation and stability. By 1907 four different processes were operating at different mines (Lynch A J, 1992). In 1912 selective flotation was developed independently at three mines (Lynch A J, 1992). Ore was treated to suppress zinc flotation in the first stage to give a lead rich concentrate and then in the second stage to enhance zinc flotation giving a zinc rich concentrate.

The fine product of the concentration plant posed a physical problem for the smelters. The answer to this and the sulphide problem was roasting and sintering. In 1892 BHP bought the British

Broken Hill Company's smelters at Port Pirie (near its own silver refining plant erected in 1889). New smelters were built and older smelters in Broken Hill closed. In early 1898 BHP closed the last smelter (Kearns R H B, 1974).

The removal of roasters and smelters from Broken Hill was of considerable environmental benefit for the population. The treatment of the tailings dumps and the stowage of waste underground was another environmental milestone. Scarcity of water resources led to its recycling in concentration plants.

The introduction of electric lighting and electric drive motors assisted greatly the productivity of the mines and the development of innovative processing plant.

Infrastructure

Until the turn of the century the Government of NSW based in far away Sydney did little for Broken Hill. It was up to private enterprise to put in place most of the infrastructure.

Railway

In 1884 the SA Government approved the building of a rail link from Peterborough to Cockburn on the NSW border near Silverton. In 1886 the NSW Government passed an Act to allow a private company, The Silverton Tramway Company, to build and operate a railway from Cockburn to Broken Hill. Curtis S L, 1908 p119 states that the NSW Government had the option to buy the railway assets after 1907 for 21years of profits averaged over the previous seven years.

The 56km line was opened by the Duke of Manchester in Jan. 1888. Blainey G, 1968 p27 states it was the most profitable railway in Australia's history. For the shareholders it was a bonanza more than the mines. Curtis S L,1908 indicates the original capital was £50,000 and that in nearly every years between 1889 and 1906 it paid dividends over £50,000 (averaging in the prior seven years £56.520). Based on return on investment this may have been the most profitable railway in the world.

The line was closed in 1969 when the standard gauge line was completed to South Australia. The Sulphide Street station in the city (completed 1905) was converted to a museum.

Early locomotive of the Silverton Tramway Company

Water

In 1890 the NSW Parliament past an Act granting the Broken Hill Water Supply Company the right to supply water in the Broken Hill district for a period of 28 years, the works at the end of that time to become the property of the Government (Curtis S L,1908 p124).This was an early example of BOOT (build, own, operate, transfer) contracts which have now been repeated a hundred years later with infrastructure such as the M2 Motorway in Sydney.

The earthen dam embankment at Stephens Creek, 17 km from Broken Hill, had solid cement concrete spillways at each end and was completed in 1892. It is possible the cement came from Australia's first cement works which commenced about that time in Adelaide. According to Curtis S L, 1908 filtered water was reticulated in 75 km of mains to over 3000 consumers in addition to direct supply to the mines.

Electricity and Gas

BHP introduced lighting to its mine in 1887. In 1889 the Gas Company began supplying its consumers and Argent Street was illuminated. Also in 1889 the York Hotel installed interior electric lighting (Kearns R H B, 1973 p34). In 1890 the Broken Hill and Suburban Light and Power Company was established and streets, stores and hotel lit up the following year.

City Tram

After turning down various proposals for electric trams over the previous 10 years the NSW Government was persuaded to install a steam tram system which commenced operation in 1902 (Kearns R H B, 1974 p22).

The tram system ceased operation in 1926.

Broken Hill Innovations

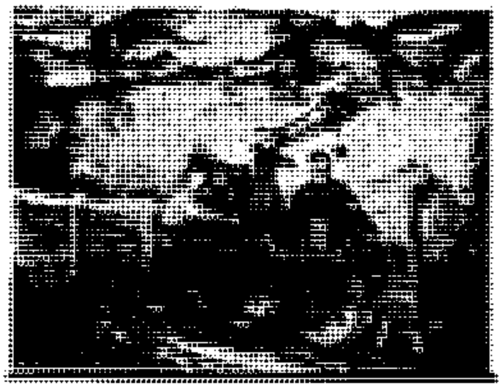
Mining

a) Square set timbering for support in wide stopes was introduced from the USA into the Broken Hill mine by John Patton in 1888. Square shaped timbers lengths, mostly imported, were set in a square pattern so they could resist pressure from all directions. Photographs between pp96 & 97 of Blainey G, 1968 show the system still in use in the 1960's. The system quickly spread to other mines throughout Australia eg. Boyle R F et al. 1993 state that method was introduced to the Mt Morgan (Qld) copper mine in 1891 after a visit to Broken Hill.

b) Open Cut mining was introduced by BHP in 1890 for cost and safety reasons in working the upper parts of the orebody. Blainey G, 1968 p102 states "the scale and system of operation was a novelty" but today "is commonplace". The open cut recovered pillars and timber left behind in earlier workings, lightened the load on workings below and provided waste for fill. Ninety years later Minerals, Mining and Metallurgy Company operated an open cut over other leases at Broken Hill (Drew G J, 1991 p6).

c) In a **world first initiative** "Cut and Fill" mining methods were developed in the 1890's by a number of mines. Above it was indicated that BHP was already using some waste rock for floor levelling in 1886. Curtis L S, 1908 p39, indicates fill was used to provide additional support and describes two mining methods used in the BHP mine. Photographs between pp96 & 97 of Blainey G, 1968 *(illustration on report cover)* show fill used with the square set system and the open stope system in the 1890's. Fill used was barren rock from the open cuts and/or sandy tailings from the concentrating mills (Blainey G, 1968 p100). The fill allowed recovery of timber and acted as a working platform as ore was removed in stages of 8ft (2.4m) above timbered haulage drives until the previous level was reached. Cut and fill systems are still used today but the fill is now only hydraulically placed residue from the mills (a system develop by Broken Hill South Company around 1940).

d) BHP introduced electric lighting to the mine in 1887 when two shafts and the smelters were lit up. (Kearns R H B, 1973 p34). While the Tasmanian Mt Bischoff tin mine installed the first lighting in 1883 (Blainey G, 1963), the BHP installation appears to be the first for an underground mine. In another first, BHP installed electric trams underground with a view of replacing horses in 1902 (Kearns R H B, 1974 p22). That year also saw the first Australian mine (BHP "Block 10" Company) with all electric drives including an aerial ropeway to transport ore from the shaft to the mill.



Electric tram in the BHP mine c 1902

e) Other initiatives introduced in the 1890's included detailed mine planning, exploratory drilling, pneumatic drilling machines, reticulated water for dust suppression while drilling and for fire fighting, and mine ventilation fans.

Minerals Processing/Metallurgy

a) In 1888 BHP erected the first concentration mill (Curtis L S,1908 p45) in a mine other than alluvial gold and tin. This had a double benefit in smelting costs –less ore to smelt, and a reduction in zinc which according to Blainey G, 1968 p54 "was such a menace in a blast furnace". Other mines followed with innovative equipment and circuits to maximise the concentration of lead and silver and the yield of concentrate. The plant included crushers to release the minerals, screens to classify material by size, jigs (which are gravity separators working with upward flowing water and mainly working on coarse material) and shaking tables, which separate fine material with across flowing water. In comparison to the ore, the lead concentration was increased 4-5 times and the silver by about 3 times and the zinc reduced by about half but there was considerable loss of metals to the tailings. However, concentration was essential for the complex sulphide ore (see Mumme I A, 1993 p348 –the sulphide problem). Jigs are still used today for appropriate ore mainly as a first pass on screen oversize to remove light hard rock such as quartz, feldspar, dolomite etc.

b) In 1890 BHP installed a plant to leach silver from ore containing little lead (Curtis S L, 1908 p46). It is presumed the leaching fluid was cyanide. (Only ammonia and cyanide will dissolve silver and silver chloride). This worked in conjunction with chloridising furnaces. The recovered silver was sent to BHP's silver refining plant at Port Pirie (started in 1889) (Curtis S L. 1908 p46). Some of this technology may have been later used in the Kalgoorlie area for gold extraction. Blainey G, 1963 p200 mentions that John Sutherland, who developed filter presses in 1897 to improve the gold cyanide extraction process, had worked at the BHP mine. After falling out of favour because of the high cost of chemicals, low metal prices and development of flotation, leaching processes are again back in favour especially for gold and copper.

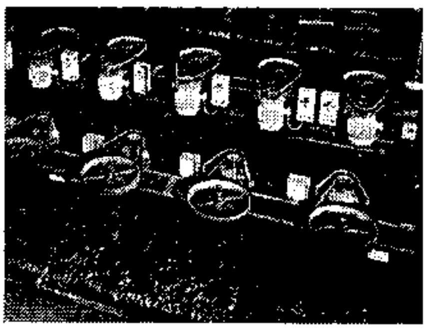
c) In 1891 Sulphide Corporation erected the first plant to attempt to recover zinc concentrates from the gravity concentration plant tailings. The plant operated in the dry state with magnetic separators. Highly magnetic rhodonite was first removed, then the slightly magnetic zinc blend (zinc sulphide). The non-magnetic quartz and lead then were treated in a wet gravity separation plant (Curtis S L, 1908 pp73 & 75). The drawbacks were dusty operation and less than desired recovery but it operated until 1908.Plants were erected at two other mines, one operating until 1911 (Mumme I A, 1993 p349)

d) The **World's first flotation process** was developed independently by Vincent Potter in Melbourne (1901) and by Guillaume Delprat in Broken Hill (1902). Both processes relied on weak sulphuric acid in a heated solution reacting with some sulphides and carbonates in the ore to give off gases which carried metal sulphides up into a scum on the surface. The only difference was that Delprat initially utilised a salt-cake waste product, which is likely to have been associated with the silver leach plant. A commercial version of the Potter process was installed by the "Block 14" company in 1903 and of the more successful Delprat process by BHP in 1904. Descriptions of the processes can be found in Blainey G. 1963 p261, Curtis S L. 1908 p47, Lynch A J. 1992 p16, and Mumme I A. 1993 p349. Curtis S L. 1908 indicates BHP had its own sulphuric acid plant for the process in 1907.

Bubbles of the flotation process carry particles of lead to the surface

e) Lynch A J. 1992 p16 mentions the development of three other flotation processes for which plants were erected in the period 1904 to 1910. These concerned processes of oil agglomeration, an oiled surface film, and generation of air bubbles by vacuum.

A modification of the oil agglomeration process developed at the Sulphide Corporation in 1905 was the real break through for flotation. It was found that small quantities of oil together with agitation by a stirrer created bubbles that floated the metals to the surface in a thick froth, which could be skimmed off. The use of Eucalyptus oil in 1909 was another important step. This is the basis of modern flotation plants.



Agitators create bubbles in modern flotation cells

f) **In another world first, selective flotation** was independently developed at three mines in 1912. Lynch A J. 1992 p18 and Mumme I A. 1993 p351 indicate that Leslie Bradford at BHP should be given credit for finding the means to depress the zinc flotation during the lead flotation (using SO_2) and then the means to enhance the zinc flotation (using copper sulphate). The latter step is still used today for zinc. (Mumme I A. 1993 p351)

Environmental Engineering

At the turn of the century Environmental engineering did not exist but there were concerns about the environment eg Blainey G, 1963 p259, Blainey G, 1968 pp87-89, and Kearns R H B, 1974 p22

Blainey G, 1968 p64 indicates that the economics for moving the smelters to Port Pirie in the mid 1890's were no more compelling than when the smelters were first erected in Broken Hill in 1886. It is likely issues raised at a committee on lead poisoning in 1892 and a subsequent Act of Parliament in 1895 (Blainey G, 1968 p89) played a part in decision making. The last lead smelter in Broken Hill was closed at the BHP mine in 1898. In 1902 G D Delprat agreed to cease roasting zinc sulphide slimes at the BHP mine (Kearns R H B, 1974 p22). (Environmental issues could be better addressed with new facilities at Port Pirie on the coast with the sea on onside)

The most notable environmental achievement, probably started by Sulphide Corporation around 1901, was the placement of barren tailings underground. Curtis L S, 1908 p69 states "The system of mullock filling of depleted areas is very complete. In the past earth and rock were quarried on the surface and placed underground for the purpose, but of late years this has been unnecessary, as the various re-treatment plants have been producing an ample supply of barren tailings, which, mixed with rock broken underground in the course of development work, make a splendid packing material." In less than 10years the large tailings dumps estimated to be more than 6.5 million tons in 1904 (Drew G J, 1991 p14) disappeared underground after treatment. This is a contrast to the more recent environmental problems with tailings eg Ok Tedi mine in Papua New Guinea.

Notable Engineers at Broken Hill Mines

1) Leslie Bradford – Engineer, Metallurgist, Member Australasian Institute of Mining Engineers (later AusIMM) from 1910, President AusIMM 1926
   Metallurgist at the BHP mine and later at Newcastle. CEO of BHP, Director of AIS and many other companies. Founder of Bradford-Kendall foundry and Bradford Insulation.
   Developer of sulphide ore roasting process
   Developer/inventor of **Selective Flotation** process 1911-1913.

2) Guillaume Delprat – Mining Engineer, President of Australasian Institute of Mining Engineers (later AusIMM) 1906-*(one of Australia's great engineers)*
   Inventor and developer at Broken Hill of a **Flotation process** for recovery of Zinc concentrates 1901-1902. Moved BHP towards iron and steel production 1911.
   General Manager of the BHP mine in Broken Hill from 1898 to about 1912 and then General Manager (CEO) of Broken Hill Propriety Ltd until 1921.

3) Sir Herbert Gepp – Chemical Engineer, Member of Australasian Institute of Mining Engineers (later AusIMM) from 1910, President AusIMM 1924
   Developer of **Flotation** plant in 1907
   General Manager of Amalgamated Zinc (de Bavay's) Ltd 1907 to 1915. (From 1915 General Manager of Electrolytic Zinc Corporation).

4) James Hebbard- Mining Engineer, Founding Member (1893) and President (1913) Australasian Institute of Mining Engineers
   Government Inspector of Mines at Broken Hill pre 1901
   General Manager of Sulphide Corporation Ltd ("The Central Mine") 1902 to +1913
   As assistant manager oversaw the first metallurgical plant for zinc concentrate recovery (1901), developer together with Minerals Separation Company of **Flotation plant** (1906).

5) Zebina Lane- Mining Engineer, Founding Council Member Australasian Institute of Mining Engineers (1893)
General Manager of BHP "Block 14" Company Ltd in 1890's, Mayor of Broken Hill
A proponent of mining and metallurgical education.

6) William H Patton – Engineer, Metallurgist- General Manager BHP mine in Broken Hill 1886 to about 1890
Introduced "Square set" roof support into Australian mines 1886 and improved mine layouts.

7) H H Schlapp- Engineer, Metallurgist, Vice-President and Founding Council Member Institute of Mining Engineers (1893)
Chief metallurgist BHP mine 1887 to 1898
Responsible for great strides in smelting technology from 1887 at Broken Hill, from 1898 at Port Pirie SA and Queenstown Tas.

8) W E Wainwright –Engineer, Metallurgist, Member 1902, Councillor 1908-1959 and President 1919 & 1930 of Australasian Institute of Mining Engineers (later AusIMM)
Metallurgist 1902-06, Manager 1906-20 Broken Hill South Silver Mining Company
Developer of **Flotation process.**

9) Captain John Warren – Mining Engineer, Metallurgist, Founding Council Member 1893 and President of Australasian Institute of Mining Engineers (later AusIMM) 1902
Pioneer in the metallurgical treatment of sulphides, developer of the Warren Vanners for separating metal concentrates from fine ore and slimes from 1893
General Manager of BHP Block 10 Company 1890 to 1902.

Social Issues

Education

In 1893 the Australasian Institute of Mining Engineers was formed at the instigation of Uriah Dudley a mine manager from Silverton and first secretary of the Institute. Many of the founding members were based at the Broken Hill mines. Amongst the aims of the Institute were reading and discussion of professional papers and circulation of publications (Dew J M, 1993 p447). The Institute must have played some part in the innovative developments at Broken Hill. At the first general meeting of the Institute there were papers on Square Set mine systems, mine planning and silver-lead concentrates (Dew J M. 1993 p454).

The Technical College at Broken Hill was established in 1897. The large building completed in 1901 in the main street (Argent street) is a historical feature of Broken Hill today. Curtis S L, 1908 p111 writes "The college receives active support from the mine managers, most of the officers on their assay staff being selected from its students."

Unions

In 1886 the Amalgamated Miners' Association (the miners union) offices were transferred to Broken Hill from Silverton. In the same year the Amalgamated Mine Managers Association was formed to represent employers interests (Kearns R H B, 1973 p17).

In 1889 there occurred Broken Hill's first major strike. This resulted in recognition of the unions for collective bargaining. Curtis S L, 1908 states more than 4000 marched in the Miners' Day procession on the first Thursday in October in 1890 after a strike lasting three weeks in September. This had a positive outcome for the miners as they achieved a reduction of working hours from 48 to 46, the lowest in Australia. In July 1892 there was a bitter strike for several months that included violence towards "free labourers" brought in to break the strike. That year

the Miners' Day procession became the "Eight Hours Day" procession. This later became Labour Day throughout NSW.

Kearns R H B, 1993 p46 indicates the strike was about working conditions. Blainey G, 1968 p88 indicates that the lead-poisoning issue may have been a hidden grievance. On the one hand the mines became more aware of bad working conditions, put in place safety policies, better mining systems and in the next years closures of smelters. Blainey G, 1968 p96 states BHP "maintained strict discipline in the interests of safety and efficiency", and on p68 gives examples such as no smoking and no drinking. On the other hand the 1892 strike collapsed and the "contract system of mining was reinstituted". It is likely that this turned the union organisers to achieving their ends through the political system.

In 1897 the NSW Government vested land under the Trades Hall Act to the Australian Labour Federation for building a Trades Hall, which was built in stages in 1898 and 1904 and is still an imposing building near the centre of town. In 1900 Broken Hill elected Australia's first Labour Mayor (Blainey G. 1968 p127). In 1901 the NSW Industrial Arbitration Act came into force and from that time negotiations for wages and conditions came under the control of the Arbitration Court. Upto that date, industrial agreements were entered into between the mining companies and unions on a 'collective bargaining ' basis (Kearns R H B, 1974 P19).

Blainey G. 1968 discusses the labour situation in pages 97 to 152. He surmises that the Act worsened labour-management relations. The evidence is clear that the strike of 1909 had a large effect on BHP. It is likely to have been a factor in BHP making a decision in 1911 to go into steel manufacture.

Heritage Significance

The unique character of Broken Hill as a large mining centre establish more than 100 years ago has been recognised by the Broken Hill Council, the NSW Government and the Federal Government. Drew G J. 1991 p4 writes "The council is actively involved in preservation and restoration of its buildings, and has a Heritage Advisory Service which provides free architectural advice to owners of heritage buildings using Council and State government funding." There are two heritage trails with about 150 features which are mostly buildings but also some remnants from mining such as shafts.

The Federal Government has granted the Line of Lode Association $4.5 million to develop a museum and mining features along the line of lode into a major tourist facility. It is understood that the one of the shafts will be restored as a working mine and that the mill and offices of the closed South Mine will be part of the complex as a museum. It is, also, understood that there will be a rail and tram equipment display.

This nomination concerns the **engineering heritage** of Broken Hill.

Statement of Significance

Heritage significance is judged against a number of criteria. These are listed below:-

1) Technical & Scientific value

   The development of the flotation process (described earlier) was a huge advance in metallurgy which benefited mining and minerals processing around the world. Lynch A J. 1992 writes "it was – properly described by Soviet metallurgists as "one of the outstanding achievements of twentieth century technology" and " it is so important as one of the greatest contributions that Australia has made to industrial technology".

(Prof. A J Lynch was Head of the Dept. of Mining and Metallurgical Engineering University of Queensland.)

Blainey G, 1963 p 271 states in 1912 (the year selective flotation was developed) small flotation plants were working in Qld, NSW and SA copper mines. Flotation spread to gold, tin, scheelite, zircon, mica, clays, limestone, manganese (and in the 1980's to coal). He rates it as one of the three great advances in the last thousand years of metallurgy.

The development of cut and fill mining systems which were only made possible with the use of barren rejects and tailings from the concentration plants also was a significant technical advance.

The Broken Hill innovations were scientifically unique, historical and of lasting benefit. They can be classified as of extreme importance.

2) Historical Value

The mines, on the world's largest orebody of its type, were Australia's first silver, lead and zinc mines. The scale of operations at the mines surpassed all other mines in Australia until after World War 1. Broken Hill became Australia's largest inland city with a population in 1901 of about 31,000. Prior to the turn of the century the major infrastructure was privately owned and operated. It became a leader in the formation of the union organization and the Australian Labour Party. It was the birthplace of Australia's first Engineering Institute (Australasian Institute of Mining Engineers) Drew G J, 1993 p293 suggests the mines are of world heritage significance.

The historical value can be classified as of extreme importance.

3) Social Value

The old mine sites and the classified buildings in the city already have immense tourism value. With the last of the mines expected to close in 6 to 10 years large amounts of money are being spent on restorations and new facilities to enhance the city's attraction for tourists.

The social value of the old mine sites and associated infrastructure is very high.

4) Landscape or townscape value

The many old buildings in the city give it character and charm. The heritage mine sites are being developed by the Line of Lode Association as an integrated tourist facility which will enhance the character of the area. (eg Junction Mine and Lookout)

The landscape and townscape have very high value.

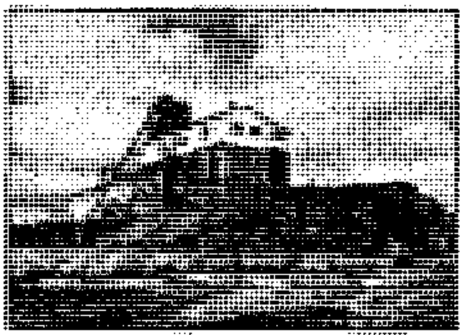
5) Rarity

The mines and associated minerals processing plants made Broken Hill unique not only in Australia but possibly in the world. There are other mining towns but none have the scale of operation, the specific type of minerals and the processes developed to treat the minerals. The range of associated buildings, housing and infrastructure also have their own unique character as an assemblage.

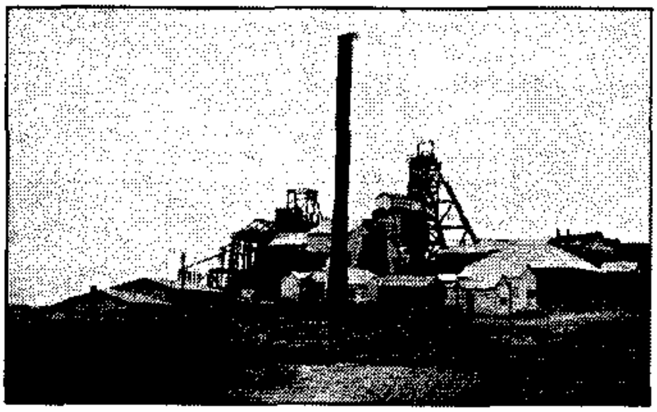
The rarity has to be classified as extreme.

65. Junction Mine and Lookout

- This site was pegged in 1884 and the Broken Hill Junction Silver Mining Co. was formed in 1886. Ore to the value of £1.2 million was produced until closure in 1923.
- The wooden headframe, the oldest remaining on the line of lode, was erected at Browne Shaft in the 1890s and has been modified several times.
- The mine was reworked by North Broken Hill Ltd between 1946 and 1962, and by South Broken Hill Ltd until 1972.
- Surviving structures include the concentration mill (1897), winding engine (1946), compressor house (1918), manager's residence (c.1916) and ore bin (c.1946).
- A 4 kilometre tunnel was driven at the 451 metre level in Browne Shaft to No. 7 Shaft at South Mine during 1962-63.



Junction Mine, 1990
At right are the foundations of the 1897 concentration mill.



Junction Mine looking north, c.1915.

Junction Mine looking north from the British Mine, c.1906. At right is the aerial ropeway which conveyed ore from Marsh Shaft to the concentration mill at the British Mine.

6) Contribution to the nation

The rich orebody at Broken Hill made a huge contribution to the wealth and welfare of the nation in the years leading upto federation. In 1901 Broken Hill had 31,000 people. It was the third largest city in NSW. The mines allowed Port Pirie to become the second largest city in South Australia. The export revenue helped Australia have the highest GDP per capita in the world. The revenue was spread far by wages, payment for goods and services (particularly to the South Australian railways), customs duties, dividends, and taxes. The dividends paid to investors helped open other mining centres particularly in Western Tasmania (Mt Lyell, Roseberry, & Zeehan)

Beside the direct monetary contribution, the mines at Broken Hill became the cornerstone of Australia's industrialisation. BHP had introduced smelting of lead (1886), and refining of silver (1890) to Australia. In 1901 they opened up the iron deposits near Whyalla in South Australia and started coke making in Wollongong. In 1915 they commenced steel making in Newcastle. BHP sold its Port Pirie smelters in 1915 to three Broken Hill companies (North, South & Zinc corporation) who expanded them to be the largest in the world. They made sulphuric acid and fertilisers. They combined as Electrolytic Zinc to erect a zinc smelter in Hobart in 1915. A different alliance went into copper smelting at Port Kembla. Zinc Corporation went on to become part of CRA which developed the Hamersley iron ore deposits and the Weipa bauxite deposits. The North and South mines invested in Paper and Pulp in Tasmania, the Commonwealth Aircraft factory and Alcoa Australia which opened up the West Australian Bauxite deposits.
No other mining centre has made such a contribution to a nation.

The contribution is classified as extreme.

7) Contribution to Engineering

The innovations in mining and metallurgy (outlined earlier) at Broken Hill made a huge contribution to engineering knowledge. With modifications some of the techniques are still in use today. The contributions arose out of practical research and development The formation of the Australasian Institute of Mining Engineers was an important step in gaining recognition of professional engineers. It helped put engineers at the head of large companies and assisted with research and development and the dissemination of technical information.

It would be of benefit to present business, government and the wider community to reflect on the achievements of the Broken Hill engineers at turn of the century.

The contribution must be classified as a minimum - very high.

Recommendation

Having regard to the heritage significance of Broken Hill and the part played by it in the development of mining and minerals processing technology and in the development of Australia as a nation, it is recommended that Broken Hill Mines and Infrastructure be recognised as a National Engineering Landmark.

Citation

Broken Hill Mines and Infrastructure

Around the turn of the century Broken Hill led the world in mining and minerals processing technology. The development of flotation has been described as one of the outstanding achievements of twentieth century technology. Broken Hill made huge contributions to the wealth, welfare and social structure of Australia. Its engineering heritage apart from its significant achievements is notable for the lack of government involvement.

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Acknowledgement

Illustrations have been copied from Blainey G, 1968 and Drew G. J, 1991 (Figures 2A&B. BHP opencut, Junction Mine Lookout)

Broken Hill, a Crucible for Research and Development in the Days of Sir Bert Gepp

I A Mumme[1]

ABSTRACT

During Gepp's lifetime, Australia was in the forefront of science and art in metallurgical practice. This did not come easily for although blessed with a unique mineral deposit at Broken Hill large in size and rich in values much courage and daring was needed in the development of processes whereby they could yield the best results.

The resultant development of the flotation processes at Broken Hill is one of the most important inventions of the 20th century.

This spectacular success was the outcome of several factors. The financial incentives to experiment on mineral processing were considerable because the old separation processes were inadequate for ores at deeper levels in the line of lode and the prize for unlocking the unsaleable zinciferous dumps lying on the surface was worth many tens of millions of dollars. Further some of the Broken Hill companies had sufficient funds from the early profitable operations on the shallow surface deposits of oxidised ores at their mines to afford the cost of countless metallurgical investigations. In addition the 'Silver City' has a number of intelligent skilful and eager men of mining and academic backgrounds ranging from the Australian gold and copper fields to Cornwall Devon Germany and the United States who were only too willing to 'give it a go'. It was also aided by the formation of the Australasian Institute of Mining Engineers (as our Institute was once called) which no doubt helped members at Broken Hill to improve their level of competence in the mining industry.

As a result of Broken Hill becoming a crucible of experimentation in the late-1890s not only did they solve their own problems but subsequent refinements of the flotation process rapidly spread throughout the world to the extent that the method is now used for the concentration of practically every mineral that is mined and is the most widely used of all methods of mineral extraction.

Apart from developing the flotation process at Broken Hill there are other areas where capital generated there did valuable work. Examples are: the improvement of smelting processes for the treatment of lead zinc and silver ores the application of the electrolytic zinc processes from the treatment of ores from Broken Hill and Tasmania the application of the differential flotation processes to low grade gold ores at Mt Morgan and the increase of efficiency of mining and metallurgical processes for the winning of telluride ores of the gold mines of Western Australia.

INTRODUCTION

With Charles Rasp's discovery of rich silver ore in a shaft sunk on a dull and manganic outcrop at Broken Hill in 1884 and later discoveries in adjacent lode capping in the following year began one of the greatest stories in mining history.

At the time the district was almost deserted. Stunted bushes covered the slopes of the otherwise bare hills and sage green tufts of saltbush hid red brown soils on the less undulating terrain.

There was little sign of habitation in this arid remote region except for two or three humpies when E H Dawson commenced his survey there on 27 August 1884.

Before long miners and prospectors flocked to the hill of mullock from nearby Silverton and surrounding districts where shallow silver-lead ores had been exhausted.

The first house built at Broken Hill was constructed on Block 14 for William Jamieson the Manager of the Broken Hill Proprietary Company which took up early leases in the area. In quick succession followed Sully's Alpha Store the Silver King Hotel Brazill and James's store then J R Stewart's bakery Neilson and Co butchery Langemeir's billiard saloon and Vaughan's Hotel. Many other buildings cottages and make-shift shelters quickly followed and Argent Street being formed soon assumed the appearance of a busy thoroughfare.

The delineated line of lode which ran north-east and south-west and boldly outcropping was soon the scene of much mining activity. Going north from the Broken Hill Proprietary mine were the properties of Block 14 British-Broken Hill Proprietary Broken Hill Junction and Broken Hill North companies. Going south from the same mine were Block 10 Broken Hill Central Broken Hill South and Block 5 mines. The properties of the Block 14 British-Broken Hill and Block 10 companies were originally leased from the Government by the Broken Hill Proprietary Company.

LEAD SMELTING AND REFINING OF OXIDISED ORES

The earliest mining operations on the great lode at Broken Hill were confined to the extraction of oxidised lead and silver bearing ores. These ores contained the lead as carbonate or cerussite and the silver largely as the chloride or cerargyrite.

After trial parcels had been smelted at the Intercolonial Smelting and Refining Co Spotswood (Victoria) and at the Daydream smelters near Silverton the ore was found to be amenable to known smelting practices.

As a result the BHP Co Ltd erected two 30 ton smelting furnaces on the field and the first ore was 'blown in' on 6 May 1886 Mrs K Brodribb performed the ceremony.

During the first year of operation some 3891 tons of lead and 52 044 ounces of silver with a total value of £385 000 were produced.

Mr H H Schlapp who became head of the company's smelting operations arrived from America on 17 April 1887. Two years later the increased ore output caused three more furnaces to be erected with 60 ft stacks to carry away the fumes.

Blast furnaces were also erected at Broken Hill by:

- The Broken Hill Proprietary Co Block 14 Co Ltd,
- British-Broken Hill Proprietary Co Ltd,
- Broken Hill South NL, and
- Sulphide Corporation NL (Central Mine).

The Broken Hill Proprietary Block 14 Co and the Junction Lead Mining Co owned smelters at Dry Creek Port Adelaide.

Early agitation for a railway to Broken Hill caused the South Australian Government to extend the narrow gauge from Peterborough to Cockburn in 1886 at a cost of £153 569. As the New South Wales Government rejected connection to Broken Hill the men of Silverton decided to build the line themselves and they formed the Silverton Tramway Co with a capital of £5000. Following government approval the line was completed and opened up in October 1886. Prior to this ores transported south were overlanded by bullock waggons to the railhead at Terowie for conveying to Dry Creek.

By 1890 the BHP Co furnaces at Broken Hill had given way to 13 water jacketted furnaces of 80 tons each. Finally the plant grew to 15 x 80 ton furnaces capable of treating 4500 tons of ore per week.

1. Friends of the Geological and Mining Museum (FOGAMM) Inc, Hickson Road, The Rocks NSW 2000.

Prospecting for supplies of suitable fluxes had resulted in deposits of iron-stone being worked at Cutana marble and calcspar quarried at Tarrawangee Purnamoota and at the Acacia Dam. Coke was obtained from England. Unfortunately positioning of the various metallurgical plants above the line of lode caused endless trouble through the settlement and subsidence of the country rock. This was in spite of the fact that it was well known on the field at the time that the lode was of immense size and that it underlay to the west.

In 1899 the BHP Co built the first concentration plant for oxidised ores. The process was to heat the ore and then concentrate using jigs buddles and vanners.

THE SULPHIDE PROBLEM

Towards the end of 1893 the higher grade oxidised ores in several mines had already largely been worked out and the problem of treating the sulphide ore became of importance. At this stage the various companies had to contend with lower grades and more complex ores.

The main body of ore now consisted of an even admixture of crystalline galena and platy zinc blende with a gangue of quartz (sometimes crystalline sometimes chalcedonic) garnet and rhodonite.

Although the gangue minerals with which the zinc blende and galena were intermixed varied materially from one section of the long line of lode to another and necessitated corresponding variations in treatment of greatest importance from the metallurgist's point of view were as follows.

Ordinary concentration of the lead sulphide now became a difficult operation and only ores above a certain grade could be treated.

The situation in the primary sulphide zone proved disastrous for the North Broken Hill Silver Mining Company because of their inability to concentrate the ore. Operations as a result ceased in November 1894 and the company went into liquidation. Others struggled on and in spite of a fall in the metal market made a small profit by dealing with immense quantities of ore.

It was now realised that ordinary concentration alone must form only a part of a more sophisticated treatment process. In an attempt to solve it the BHP Proprietary Co built the first concentrating plant for treating sulphide ores at Broken Hill. This plant was equipped with collom.jigs Cornish buddles and frue vanners.

Other companies had parcels of ore tested at Wallaroo and Moonta. Block 10 Co sent a parcel of ore to Freiberg and Grube Hammelfahrt in Germany for treatment by the 'Lubig' process of concentration and some forwarded sulphide ore to Swansea in Wales. Subsequently other concentrating mills were erected at Broken Hill by:

- Broken Hill Proprietary Block 14 Co Ltd,
- Broken Hill Proprietary Block 10 Co Ltd,
- Central Mine,
- Broken Hill South NL, and
- Junction Lead Mining Co Ltd.

About 1901 the 'Luhrig' vanners were replacing the buddles in the mills and the Wilfrey table was coming into use treating the coarser portion of the slime: thus a concentration plant at Broken Hill between 1900 and 1904 had as general equipment the following items: Crushing rolls raff wheels spitz kasten Hancock jigs May Bros jigs Herberle disc grinders Wilfrey tables buddles or 'Luhrig' vanners.

Due to the mutual interference of the lead and zinc contents of the sulphide ore all the most efficient mills could do with these ores was to crush them and then divide them by their conventional gravity methods into two heaps. The first heap contained about two thirds of the lead about half of the silver and about one sixth of the zinc. This lead concentrate went to smelters in Australia, Belgium and Germany and yielded the lead and silver.

The zinc contained in this lead concentrate on the other hand fused in the furnace with the ironstone flux and was tipped on slag dumps at Port Pirie where a smelter had been established in 1908 and those European smelters which bought Broken Hill sulphides trapped enormous quantities of zinc. Not only did it destroy for ever the chance of obtaining the valuable metal zinc from the lead concentrate but was such a menace in the blast furnaces that smelting companies exacted penalties on a sliding scale.

While both the concentration and smelting methods adopted to solve the sulphide problem served to prolong the lives of some of the mines yet both in themselves were wrong in concept and the further they were persisted in the worse had become the position of the mines.

The most expensive failure of a plant for treating sulphides from Broken Hill was one constructed by Sulphide Corporation (Central Mine) at Cockle Creek New South Wales. It was based on a process invented by Edgar Ashcroft. He planned to separate the silver-lead and zinc minerals by roasting and leaching and recover the zinc by the then untried controversial electrolytic process and ship the silver-lead residues to Port Pirie where a smelter had been constructed for refining lead ores.

With the process passing all tests at the laboratory stage in Australia and London and with the sanction of the famous German metallurgist Dr Carl Schnabel an expensive plant was constructed at Cockle Creek just south of Newcastle. It commenced operations on 7 April 1897 but unfortunately the process did not live up to expectations and operations terminated on 28 July of the same year.

It is interesting to note however that at that stage the Sulphide Corporation had advanced the electricity process for the recovery of zinc further than anyone else in the world but could not make it an economic proposition. Perhaps they might have succeeded if the flotation process (which was still a few years off) had provided them with the raw materials more amenable to the Ashcroft process.

As a result of the scrapping of the Ashcroft plant along with numerous failed attempts to reclaim the zinc from the huge dumps that were accumulating along the line of lode many felt that the whole of the chemical possibilities for the separation of the lead and zinc had now been exhausted.

MAGNETIC CONCENTRATION

In 1899 a different approach to the sulphide problem based not on chemical but on magnetic concentration was tackled. As a result a pilot plant was erected by the Australian Metal Co at West Broken Hill to test and treat the tailings.

Early in 1900 the Sulphide Corporation at the Central Mine imported a test machine from Meckernick Electro Magnetisch Gesellschaft of Germany and made a series of experimental runs. Following favourable results the No 1 magnetic plant of that company was erected and put into operation in July 1901.

This equipment although creating much dust opened up a new field in the metallurgical concentration of ores and zinciferous dump material at Broken Hill. Now magnetic materials such as garnet and rhodonite which previously could not be separated from zinc blende by gravity methods of concentration could be removed in the clean state and devoid of any metalliferous matter.

Despite the accompanying dust problems and electrical hazards the magnetic plant continued operating until 31 August 1907 by which time it had treated some 200 000 tons of concentrates.

A second magnetic plant was put into operation at the Central Mine in December 1904 and worked until 1908.

Although only partially successful it must be said that George Ullrich Manager of the Australian Metal Company works at the 'Hill' did an immense amount of useful work in introducing the magnetic separators and in showing that the vast heaps at Broken Hill could be profitably dealt with.

The company purchased some 66 000 tons of tailings from the Central Mine and 100 000 tons from Block 10. They had already dealt with 130 000 tons and believed that they could have treated all the remainiug dump material in a single year.

The first machines made use of were the Wetherby but they were soon discarded and Ullrich machines used. The last machine was scrapped in 1911. It is interesting to note that a Mr Odling of the adjacent Pinnacles Mine developed a special conveyor belt system which proved effective for magnetic processing of the ores at that mine.

However in spite of the installation of expensive conventional mechanical equipment and the introduction of the magnetic separation equipment none of the six companies operating treatment plants in Broken Hill had found an adequate solution to the sulphide problem. The best mills were still only recovering two-thirds of the lead half of the silver and very little of the zinc which was still largely going into growing mountains of tailings.

Taking the eommercial value of the products that is clean lead concentrates clean zinc concentrates and their silver valves distributed equally in each it may be said that more than half of their value was lost.

No wonder there was an air of pessimism at Broken Hill at that stage and informed men including Guillaume D Delprat were predicting the imminent collapse of the mining field if the sulphide problem could not be solved.

Fortunately however when the zinc problem was the question of the hour men like Delprat as well as Baillieu Gepp Robinson Hoover Govett and others of acumen enterprise and energy took up the challenge.

DEVELOPMENT OF FLOTATION PROCESSES

Guillaume Daniel Delprat had become the fourth general manager of the Broken Hill Proprietary Co already Australia's largest mining and industrial company in 1899. An outstanding figure in the history of the company he brought a wealth of engineering and managerial experience gained from demanding posts in England Canada and Spain to bear on the formidable problems at Broken Hill. His household became a focus of social life at the 'Hill'.

While not hopeful about the future of the Big Mine late in 1902 he decided to try a radical departure to the traditional practices to solve the zinc problem. He asked his metallurgist A D Carmichael to dissolve a sample of zinc rich tailings in an aqueous solution of salt cake - a waste product from the mine's sulphuric acid plant.

After boiling the material was allowed to settle before the liquor which was boped to contain zinc solution was filtered off. To their surprise the scum which had formed at the surface of the liquid on cooling was recognised as zinc blende while the sandy useless matter had collected on the bottom of the vessel.

Realising the importance of this test Delprat telegraphed the exciting news to the Melbourne head office. As a result, further experiments continued at the Proprietary Company to devise a large scale plant to separate zinc sulphide from the residues using salt-cake.

While a plant was being constructed to operate the Delprat pan as the new mineral separation process was known an ingenious Melbourne inventor and chemist Charles Vincent Potter had successfully demonstrated in Port Adelaide that he could separate zinc sulphide from a pulp of tailings and water with bubbles released from treating them with sulphuric acid.

In November 1901 Potter obtained patent No 18775 for the recovery of sulphides from their ores by means of separation effected by dilute acids. He found that certain sulphides when treated with highly dilute acids and warmed to nearly boiling point rose from the rest of the crushed ore and could be either skimmed off or floated away.

Being a chemist he no doubt was quite familiar with the floating action of ground particles of sulphides while being digested in acids during routine assay procedures. This phenomenon must have looked too fanciful to many metallurgists at that time although apparently not to Delprat.

The explanation of the process is that if there are mixed sulphides in an ore on warming with dilute acid the sulphides are attacked at once creating gaseous bubbles which attach themselves to the particles and in the course of time so increase in size as to lift them to the surface. The effect is further enhanced if calcite is present in the ore. On a theoretical basis chemical studies suggested that about 7½ lb of sulphuric acid was sufficient to generate enough gas in the run of mill tailings to float one ton of zinc blende or one part by weight of sulphuric acid would float 300 parts of zinc blende. Further if the acid was heated to near boiling point the calculations suggested 5½ lb of acid would suffice to float that quantity of zinc blende. This looked very encouraging.

Assistance in commercialising Potter's patent came from various quarters. For example when G A Goyder one time analyst with the South Australian Mines Department was heating some Broken Hill sulphides in an inclined test tube filled with sulphuric acid he observed that bubbles with their sulphide load travelled up the smooth side of the tube until they met the surface when they fell vertically until they impinged on the lower side of the tube down which they glided and he could see a simple mechanism for separating sulphide from gangue material present in the ore. He concluded that if a pocket was present on the underside of the inclined tube the sulphide granules would gather there. He made such a tube and found it worked to his complete satisfaction.

Various operative flotation machines were developed by Potter based on Goyder's observations. One called the Goyder-Laughton had a capacity of one ton per hour. It was later refined by a Mr Berry of Melbourne who did away with all the chains and pulleys present in the original machine and employed a shallow cylindrical vessel possessing a circular launder or trough around its circumference. An inverted cone placed at the centre of the launder served as a deflecting surface which enabled an overflow of water to carry zinc blende into the trough further on the trough contained more lead concentrate and at the discharge point still more. Other machines were also devised which had less moving parts and again used flowing solutions to effect a separation of sulphide and gangue material.

Four Goyder-Laughton flotation machines were erected on Block 14 mine and operated from November 1903 to March 1904 when they were replaced by the Delprat pan because of expensive maintenance. The Delprat pan resembled the Potter's process except that salt-cake was used instead of dilute sulphuric acid which was believed to be more efficient in floating the sulphide matter because of the higher density conditions prevailing.

Soon after Potter developed his process Zinc Corporation applied it to recovery of zinc from tailing dumps from the Central Mine but because good results were not obtained as with the earlier minerals separation process applied it adopted the Elmore Vacuum process on the recommendation of Herbert Hoover the eminent American mining engineer who returned to Australia in 1905. By its means the fortunes of the Corporation were retrieved and for some years (from 1908 to 1910) large amounts of tailings were profitably treated. In the meantime however the minerals separation process was perfected and in 1910 it replaced the vacuum process.

About that time a Process Investigational Committee comprising H W Gepp (General Manager of Amalgamated Zinc de Bavay Company) and W E Wainwright (General Manager to Broken Hill South Ltd) was authorised to investigate any process that would prove of value in the treatment of slimes.

In 1913 T M Owen the Mill Superintendent of the Junction North Mine patented a subaeration flotation process. He had observed in trial runs that by introducing a stream of minutely divided air bubbles in the pulp at or near the bottom of the separating vat or by regulating the said stream of air bubbles he was able to successively float concentrates - first the more readily flotable galena and then the less readily floated sulphides such as zinc blende.

While Lyster and Owen contributed to the development of differential flotation it was in fact Leslie Bradford who made the important discovery that by adding a small amount of copper sulphate to the brine solution any sulphides remaining in the residues would be floated when subjected to aeration conditions. This made the differential flotation technique an assured economic success and copper sulphate is now used throughout the world by every flotation mill recovering a zinc concentrate.

Although it is difficult to assess the true value of the flotation processes to Broken Hill and the other mining fields that adopted them there is no question that Broken Hill's zinc problem was solved by the application of the several proved flotation processes.

Not all of the 12 companies installed flotation plants because two new treatment firms Amalgamated Zinc de Bavays and the Zinc Corporation built modern plant to treat zinc tailings from the zinciferous tailings dumps and those from current operations.

Amalgamated Zinc had developed to employ de Bavay's process while the Zinc Corporation was established initially to treat tailings purchased by Herbert Hoover.

Both companies were strongly backed by London and Melbourne financial groups.

The successful adoption of the flotation processes at Broken Hill led to its use in copper mining and gold mining and a host of other industries.

The high grade zinc concentrates from the flotation plants made possible the success of the first large scale distillation plant at Port Pirie in 1908 for spelter manufacture. Later from 1916 to 1922 the electrolytic zinc industry depended upon its products for raw material. While its contribution to the national economy was considerable to the Broken Hill Proprietary Co it facilitated enormous industrial and resource development by providing sufficient financial reserves.

With the flotation process up and running Delprat now saw the potential of the vast quantities of exceptionally pure iron ore deposits on the company's leases at Iron Monarch and Iron Knob and the need for an iron and steel industry.

In 1911 he presented an ambitious plan to the board of directors of supplying ever expanding Australian iron and steel needs then met by expensive overseas imports. After exhaustive investigations his plan was adopted and the BHP's operations took on a bold new coarse of extensing their undertakings to the manufacture of iron and steel at Newcastle. The plant commenced operations on 2 June 1915.

Just as the immensely rich alluvial gold discoveries populated the country and aided its development in the 19th century so it was Broken Hill discovered in 1883 which provided the raw material and capital for a great deal of development in the 20th century some of which had been the subject of this paper.

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Broken Hill Metallurgy - A Story of Innovations in Processes, Equipment and Instruments

A J LYNCH[1]

ABSTRACT

Broken Hill metallurgists have been responsible for some of the most important developments in mineral processing technology. These occurred mainly in two periods, 1902 - 15 and 1955 - 70. Mineral flotation was developed as an industrial process during the first period and this happened in two stages, the recovery of zinc minerals from the tailings dump accumulated during the gravity concentration of the oxidised ores and the selective recovery of galena and marmatite during flotation of the primary ores. During the second period fast accurate analytical procedures were developed to provide rapid assessment of process performance, and new means of controlling the process were devised which improved throughputs, grades and recoveries.

These technological successes were due to the skills of the metallurgists and the commitment of the companies. They brought large financial returns. They were achieved under difficult circumstance. There are important lessons to be learnt from these successes.

INTRODUCTION

In his Presidential Address to the Institution of Mining and Metallurgy in 1984 Philip Grey commented on the great influence which 'Broken Hill type metallurgy' had on metallurgical operations (Grey, 1984). He noted that 'the character of the deposit played a major part in the evolution of differential flotation, the electrolytic zinc process, blast furnace smelting of lead, the ISF and continuous lead refining' and that the influence of flotation has been so great that it has been applied to ores 'the mineralogy of which is quite unsuited to it' with poor results.

The flotation process was developed at Broken Hill during 1902 to 1915 to produce high grade mineral concentrates from a fine grained (as it was regarded at the time) polymetallic sulphide ore body. It was a remarkable achievement and was properly described by Soviet metallurgists as 'one of the outstanding achievements of twentieth century technology' (Klassen and Mokrousov, 1963). Its development was reviewed by the Broken Hill Branch of The Institute in the Proceedings of the Australasian Institute of Mining and Metallurgy (1930) but it is so important as one of the greatest contributions that Australia has made to industrial technology that it will be described again briefly in this paper.

Fifty years after success with flotation Broken Hill metallurgists were again at the forefront of science and technology in mineral processing, this time with new instruments and techniques to improve the productivity of the concentrators and the quality of the products. New analytical techniques were developed, new methods were devised to control the grinding and flotation processes and a new flotation cell was designed to enhance the efficiency of the process.

The theme of this Conference is 'The State-of-the-Art A Product of 100 Years of Learning'. Broken Hill metallurgists have had much to do with the State-of-the-Art in mineral processing through their innovations in processes, equipment and instruments. The reason for writing this paper is to review their successes, and to identify the reasons which might assist us today in our search for further success.

FLOTATION: 1902 - 1915

There were several major improvements in metallurgical processes at the end of the 19th and the start of the 20th century. Metallurgists were faced with major problems in milling and smelting because the higher grade ores were exhausted and it was necessary to treat the lower grade refractory ores. To solve these problems several new concentration processes were developed and flotation was the most important. The financial consequences of flotation were enormous. It was because of flotation that copper could be produced economically from low grade porphyry ores, commencing with the Bingham Canyon ore in 1907, and it was because of cheap copper that distribution of electricity was possible. It was also because of flotation that lead, zinc and other metals could be produced on a large scale efficiently and economically.

The research work which was carried out during 1902 - 1905 focussed on the surface properties of the minerals as the basis for concentration. The idea was not new, patents relating to mineral concentration by agglomeration or adhesion to air bubbles had been taken out in England (Haynes, 1860) Germany (Bessell, 1877, 1886) and USA (Everson, 1885) but no industrial process had followed from the patents. Whether the idea for flotation was picked up from the literature or heard about in some other way by the Broken Hill metallurgists, or whether it was developed independently, is not important. What is important is that flotation was developed as an industrial process on a large scale at Broken Hill and it was because of flotation that Australia became a world leader in the production of zinc concentrates within a few years.

The success of the research programs was such that by 1905 there were four large experimental flotation plants operating in Broken Hill to separate the zinc mineral from the tailings. The machines used in these plants showed an extraordinary degree of technical innovation and it has only been in the last few years that there has been some activity in replacing the machines developed in those days by other flotation devices.

In retrospect it is not surprising that flotation was developed at that time. It was a remarkable period in mining and metallurgy. Discoveries of great mineral deposits were made in many countries in the 1880s and 1890s, and many new smelting, leaching and concentration processes were developed which greatly enhanced the ability of the engineers to exploit those deposits.

Australia was an important participator in those developments. The ore deposits at Broken Hill, Mount Morgan, Mount Lyell and Kalgoorlie were discovered during 1883 - 1895 and innovations in gravity concentration at Kapunda, smelting at Mount Lyell and gold processing at Mount Morgan during the 1880s and 1890s established Australian metallurgy as an important factor on the world metallurgical scene. The stage was set for the invention at Broken Hill which was to transform metallurgy.

Stage one: 1902 - 1905

Blast furnace smelting commenced at Broken Hill in 1886 and the first of the gravity mills to concentrate the oxidised ores was built in 1889. Initially the efficiency of the gravity concentrators was poor but it rapidly improved for lead and silver although it continued to be poor for zinc. Gravity concentration of the sulphide ores which lay under the 100 metre deep oxidised zone commenced in 1894 and was inefficient even for lead and silver. Magnetic separation and hydrometallurgy processes were tried on the sulphide ores but without success.

By 1900 the companies working on the line of lode were faced with the problems that the oxidised ores which could be mined and processed profitably were being depleted rapidly. There was

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no metallurgical process known which could be used to efficiently extract zinc from the mountains of tailings (See Table I) or silver, lead and zinc from the large reserves of primary ores. The main advantages which the companies had in solving the metallurgical problem were that they were strong financially and technically, and they had incentive, ability and determination.

Potter - Delprat process

This process was developed independently by Vincent Potter (1901) and Guiliaume Delprat (1902) and it involved floating the sulphide minerals on bubbles of carbon dioxide generated by a hot acid solution acting on the carbonates in the ore. The combined Potter - Delprat process was used at the BHP company until 1923. The Potter - Delprat process produced millions of tonnes of zinc concentrate and it was the first of the successful mineral flotation processes.

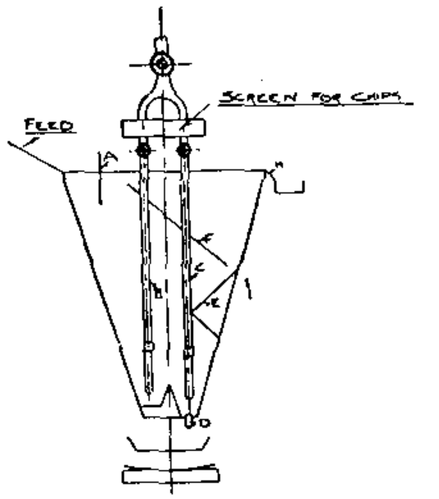

FIG 1 - Potter - Delprat process (Broken Hill Branch, The Australasian Institute of Mining and Metallurgy, 1930).

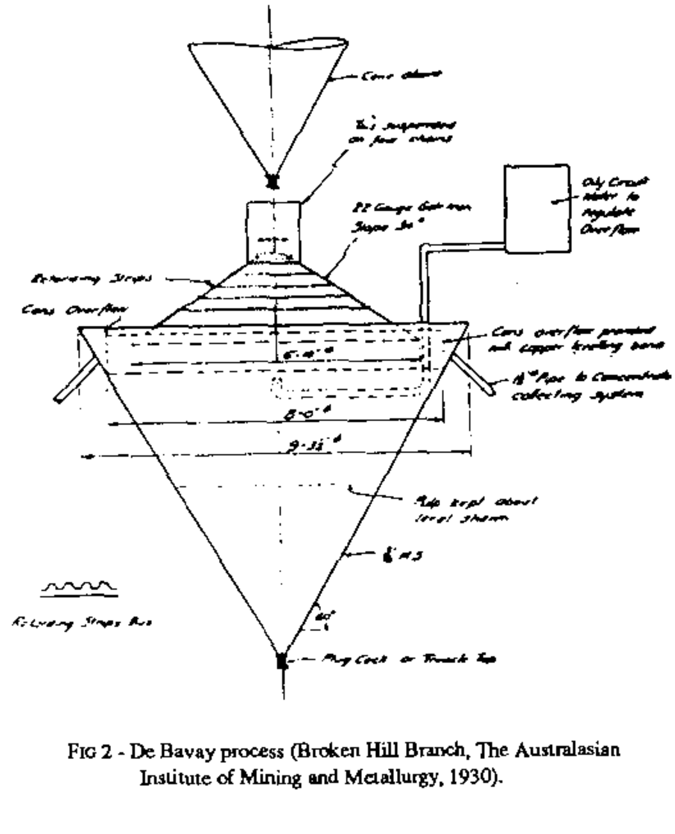

FIG 2 - De Bavay process (Broken Hill Branch, The Australasian Institute of Mining and Metallurgy, 1930).

Cattermole process

This process grew out of an attempt to agglomerate selectively the sulphide minerals.

Oil was added to the agitated pulp, it selectively adhered to the sulphide particles and they agglomerated. Separation of the agglomerate took place in a jig or hydraulic separator. The Cattermole process was tested with some success at the Sulphide Corporation (1904) and it was then purchased by the Mineral Separation Company in England. It changed into a more conventional flotation process by adding less oil and agitating violently to induce air into the pulp. The air bubbles adhered to the oiled sulphide particles and the mineral froth was removed as a concentrate. In due course violent agitation was replaced by a stirrer and it was the Cattermole Mineral Separation process involving a stirred tank which evolved into the modern day stirred flotation machines.

De Bavay process

This process involved adding oil to the mineral water pulp and running the oiled particles down the outside of an inverted cone in a thin film of water in such a way as to expose the particles to the air. The film of pulp then flowed on to the top of water in the settling cone. The sulphide minerals floated on the surface of the water and were removed as a concentrate. The De Bavay process was tested in an experimental plant in 1905 and it operated on a large scale from 1910 to 1917, treating large quantities of tailings.

Elmore process

This process involved applying a vacuum to the pulp precipitating the dissolved air as bubbles on the particles and float the sulphide particles as a froth. The Elmore process operated at various Broken Hill mines, including the Zinc Corporation, Block 10 Company, British BHP and the Pinnacles Mine during 1907 - 13 and treated large quantities of dumped material.

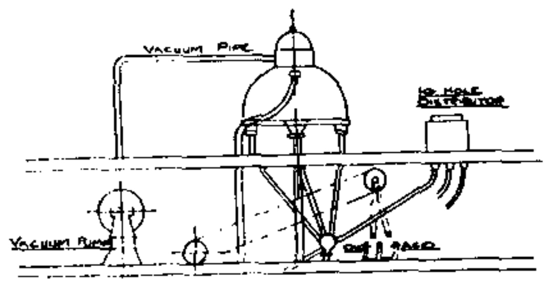

FIG 3 - The Elmore process (Broken Hill Branch, The Australasian Institute of Mining and Metallurgy, 1930).

Discussion

It is difficult now to imagine the excitement which must have existed at Broken Hill in those years from 1902 - 1905 as metallurgists struggled with the vagaries of this revolutionary process. At times the processes worked superbly and at times they did not work at all. Secrecy was the order of the day because of the patent situation yet the plants were either in sight of one another or easily visible from the public roads. The environment for applied research was quite different then from that to which we are accustomed today. There was total commitment to success, strong leadership, no interference from and certainly no support by government, laboratories which were primitive by today's standards and few of the amenities of present day civilisation. It was a time of high achievement in metallurgical technology in adverse conditions.

There was an inevitability about success. The stakes were high, the technical strength was right for the task, the resources were adequate and the leadership was totally committed. And the

TABLE 1

Accumulation of tailings in dumps by 1904 (Broken Hill Branch, The Australasian Institute of Mining and Metallurgy, 1930).

Mine	Material	Tons	Assays		
			% Pb	Oz Ag	% Zn
Broken Hill South	Tailing Slime	620,000 100,000	7.2 14.6	4.2 6.4	19.7 18.4
Central Mine	Tailing Slime	1,000,000 600,000	7.0 17.0	6.0 20.0	22.0 21.0
Block 10 Company	Tailing Middling Slime	520,000 137,000 165,000	520,000 137,000 165,000	9.5 10.5 9.0	22.0 22.5 18.0
BHP Company	Tailing	2,500,000	4.0	6.0	17.0
BHP Block 14 Company	Tailing	250,000	7.0	6.5	16.5
British BHP Company	Tailing Slime	250,000 125,000	4.8 8.9	5.0 10.0	17.0 21.0
Junction	Tailing Tailing Slime	10,000 60,000 25,000	16.0 7.0 12.0	10.0 7.0 12.0	19.0 12.0 13.0
Junction North	Tailing Slime	95,000 5,000	10.0 11.0	9.0 12.0	12.4 13.0
	Total	6,582,000			

TABLE 2

Zinc concentrate produced from the toilings at Broken Hill by flotation, 1904 - 12 (Broken Hill Branch, The Australasian Institute of Mining and Metallurgy, 1930).

Year	Tons zinc	concentrate produced
	Yearly total	Progressive total
1904	57,602	57,602
1905	103,532	161,134
1906	102,664	263,798
1907	236,251	500,049
1908	275,932	775,981
1909	373,906	1,149,887
1910	468,627	1,818,514
1911	516,378	2,134,892
1912	520,518	2,655,410

success which was achieved gave Australia a world class zinc industry within a few years.

Stage two: 1910 - 1915

Flotation matured as an industrial process during 1905 - 10. It was successful in extracting zinc from the dumps but less successful in producing separate lead and zinc concentrates from the primary sulphides, only a bulk concentrate could be produced. This concentrate incurred penalties when sold to the smelters and the financial losses which resulted led to another major effort during 1910 - 13 to develop differential flotation. As in the previous phase many metallurgists contributed to the solution of the problem and in this paper reference will be made to two in particular, Fred Lyster and Leslie Bradford.

Lyster process

Fred Lyster was a carpenter by trade who was appointed superintendent of the small Zinc Corporation Limited mill. He noticed that a froth containing high lead and silver was formed on the top of the pulp in dewatering cones when used in a circuit treating tailings. He then experimented with direct flotation of fresh primary ore in neutral and alkaline solutions containing eucalyptus oil as a frother and he obtained encouraging results (Lyster, 1912). Within months a circuit was operating at Zinc Corporation which led to the production of lead concentrate which was despatched to the BHP Company smelters at Port Pirie. A similar process was patented by T M Owen at the Junction North Mine. Both processes were found to give a good grade of lead concentrate and high recovery of lead and silver, and a zinc middling with poor recovery of zinc.

Bradford process

Leslie Bradford was the metallurgist at the BHP Mine who pioneered the concepts of mineral activation and depression and who through this discovery made the greatest contribution to differential flotation as we know it today. Potter and Delprat through their patents can be given credit for the concept of industrial flotation but it was Leslie Bradford who should be given credit for "The Broken Hill type metallurgy" of which Phillip Grey wrote. Bradford developed the following processes:

1. The acidified salt solution process to float a zinc concentrate from a lead/zinc bulk concentrate (Bradford, 1912).
2. The coppersulphate process to activate zinc after lead flotation. (Bradford, 1913a)
3. The sulphur dioxide process to depress the zinc in lead flotation (Bradford, 1913b).

This was a remarkable series of achievements by a man who through his work in mineral processing at Broken Hill, pyrometallurgy at Newcastle and, physical metallurgy at Sydney, proved himself to be one of the great metallurgists of modern times.

Discussion

Differential flotation was progressively installed in the nine Broken Hill concentrators during 1912 - 1918 and by 1920 Broken Hill type metallurgy was well established. The supply of high grade lead and zinc concentrates led to advances in lead smelting and refining at Port Pirie inspired by G K Williams, and to the construction of the electrolytic zinc plant at Risdon under the direction of H W Gepp. Both men made great contributions to Australian metallurgy and this was possible because of the flotation process developed at Broken Hill.

The importance of the engineering innovations in the development of flotation machines at Broken Hill must not be underrated. Flotation was a success only because of the initiative of the metallurgists and engineers in designing and building a wide range of machines to work on principles which were, at best, vaguely understood.

The next 40 years at Broken Hill was a period of consolidation and improvement. Metallurgical standards were high and there can be no doubt that during those years Broken Hill led the world in its mineral processing technology. One limiting factor was the relative isolation of the town and the lack of communication with engineers from other disciplines. Consequently the ideas which were developing in other disciplines were not being incorporated into Broken Hill technologies, but the Second World War changed all that.

PROCESS MEASUREMENT AND CONTROL: 1955 - 1970.

A centralised control system 1955 - 1960

The ingredients for a major change in mineral processing technology which were present in 1902 also were present 50 years later and again major improvements occurred this time by substantial improvement in efficiency and productivity. The rewards in this case were derived partly from Broken Hill operations and partly from other mining leases held by companies which had their origins in Broken Hill because by then the Broken Hill companies had expanded far beyond their original base. On this occasion it was the metallurgists at the Zinc Corporation Limited who were mainly responsible for technological change.

The background to the events which were to occur was that the Zinc Corporation Limited and its parent company Consolidated Zinc had a management team which demanded technical superiority. There was no concern about secrecy, their concern was that the operations should be the best in the world. Their aspirations were matched by the desire of the people who had returned from service in the armed forces to bring to the Broken Hill operations some of the ideas which they had learnt from wartime colleagues who were engineers in other professions. The concentrators in Broken Hill at that time had excellent processing systems but there were operating inefficiencies due to the inadequacy of the control systems. The main problems were:

1. Inaccurate measurement of ore tonnage processed and of mineral pulp densities within the circuit.
2. Up to 28-hour lag-time in the return of assays for the assessment of plant performance.
3. Total dependence on operators for control of the grinding and flotation circuits.

It was evident that a large improvement in efficiency could be achieved by process measurement and control systems but the problem was that there were few suitable online measurement instruments available for use with mineral pulps.

Consequently a major program was established to develop the important instruments. It was also necessary to develop better understanding of the processes so that feedback control systems could be implemented. The instruments which were developed early in the program included:

1. A pneumatic probe to measure the density of mineral pulps so that the pulp density of the classifier overflow and the circulating load in the flotation circuit cleaner tails could be controlled.
2. A probe to measure the residual xanthate in pulp streams which could be used to control reagents added to the flotation circuit.
3. A rapid analysis system based on xray fluorescence to give operators information about plant performance within two hours.

The work progressed successfully and the decision was taken to install a pneumatic control system at the Zinc Corporation Limited in 1958 which was operated from a central control room. This was the first of its kind in Australia and was a leader in the world at the time. It quickly repaid the investment with large improvements in productivity and product quality.

New instruments and machines - 1960 - 1970

Three major developments occurred during this period. The first was concerned with atomic absorption spectroscopy. This technique had been proposed and demonstrated by Dr. Alan Walsh of CSIRO but was still a curiosity when Bruce Rawling, Chief Chemist at the Zinc Corporation Limited, heard of it and recognised its potential for solving an important assaying problem which was concerned with the silver contents of lead concentrates. Rawling quickly demonstrated its value and its installation at the Zinc Corporation Limited gave atomic absorption spectroscopy a major impetus (Rawling *et al*, 1961). Oddly enough the real benefit to the company came with its use in mineral exploration where it proved to be a particular boon.

The second development was concerned with onstream analysis in mineral concentrators. X-ray stations to which samples were pumped from selected points in the concentrators were then being used in concentrators in the United States but they were failing because of difficulties in pumping. Metallurgists at North Broken Hill Limited were the first to develop a radioisotope gauge to measure the lead content of flotation feed and they did this by mounting two sensors on the flotation feed pipe (Ellis *et al*, 1967). The gauge was satisfactory for the purpose and was an important advanec. Metallurgists at the Zinc Corporation Limited then had the idea of using an isotope probe immersed in the flotation pulp to give metal contents at different points in the circuit and in collaboration with physicists from the

Australian Atomic Energy Commission they developed a suitable probe (Hinckfuss and Rawling, 1968). This probe was very successful and ultimately was sold to a world wide market. This was an example in which research carried out by metallurgists at mines resulted in the development of an instrument manufacturing industry which competes successfully in the world market.

The third development was concerned with a new type of flotation cell. New cells are in vogue today but in 1965 there had been little change in cell design for 50 years. The idea came from a paper written by Denis Kelsall in which he suggested that flotation was a probability process (Kelsall, 1960). Bill Davis (1964) at the Zinc Corporation Limited recognised that the recovery of mineral from a flotation cell depended mainly on the cell mechanism and the adjacent pulp zone rather than the cell volume, and that a small improvement in recovery from a flotation cell could have a very significant effect on the capital cost of the flotation section of new plants or on the capacity of existing plants. He looked at methods which were then used for mixing gases and liquids. This led to the idea of the mixing nozzle and to the development of the Davcra flotation cell. First tests indicated that significant improvements in recoveries could be achieved by intense mixing of air and pulp outside the cell and by using the cell as a zone for separating the froth from the pulp (Cusack, 1968). The Davcra cell was ahead of its time but it is interesting that it is now being used successfully in Africa, and the concept on which it is based is being marketed as a new cell from Germany.

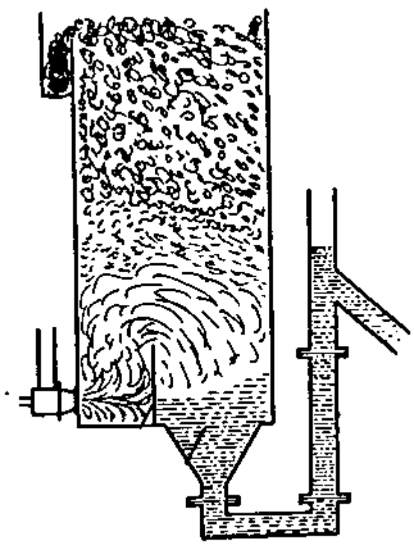

FIG 4 - The Davcra cell (Cusack, 1968).

Discussion

For a period of 15 years after the Second World War, Broken Hill was again at the forefront of mineral processing developments. Broken Hill of 1955 was very different from Broken Hill of 1915. Six of the nine companies had gone and the only companies remaining were North Broken Hill Limited, Broken Hill South Limited, and ZCNBHC Limited. Again there was competition between metallurgical groups but this time it was in a co-operative rather than an secretive sense. About 30 metallurgists were employed at Broken Hill during each period. This group was large enough to respond positively to encouragement from senior management and to generate new ideas.

The question now is what can we learn from these periods of metallurgical success, which will assist us in the future?

BROKEN HILL METALLURGY THE LESSONS FOR THE FUTURE

The Broken Hill mines were the success story of Australian industry in the 20th century. Through their efforts Australia was among the world leaders in the production of lead and zinc concentrates and in metals. From the Broken Hill companies came many of the great enterprises that have done so much to develop Australia, the base metal industries, iron and steel, aluminium, oil, pulp and paper, aircraft manufacturing and others.

There were four reasons for success. First and foremost the orebody was immense and high grade, and capable of generating the large revenues which are a necessary basis for industrial development. Many orebodies which have been exploited in Australia and overseas have also been large and high grade, but they have not contributed to industrial development on the same scale, nor have they seen technical innovations of the same magnitude as those which have come from Broken Hill. The second reason was that the Boards of Directors of the Broken Hill companies were farseeing and were always prepared to support and encourage technical development to the hilt. It is not that the difficulties of today were unknown then, those Boards had to cope with high labour costs, exacerbated by a spiralling lead bonus, high government charges due primarily to excessive royalties, and high rail freights because of the unusual circumstance by which two companies, the Silverton Tramway Company and the South Australian Government Railway Department, participated in the transport of the concentrates from Broken Hill. Yet the commitment of the Boards to research and technical development for many years was unhesitating. The third reason was that the group of metallurgists at Broken Hill exceeded the critical size which is necessary to generate new ideas. The fourth reason was that there was a clear understanding of the economic benefits which a success in research would bring.

Australia is fortunate that it has large high grade orebodies which are among the best in the world and more such orebodies will undoubtedly be discovered. However our pre-eminence in metallurgical technology, to which Broken Hill contributed so strongly, is not obvious, as it was previously, although significant developments are still occurring. Provided that the lessons from Broken Hill are learnt and applied there is no doubt we will resume our world position of pre-eminence, with all the financial gains and the new industries this will bring.

Both of the great metallurgical developments at Broken Hill coincided with periods of major international technological change. The first coincided with the surge in industry due to petroleum and electricity, the second with the surge which followed the Second World War. It is clear that developments in computers and communications, and the world population explosion, place us now on the threshold of another period of major technological change. It is clear also that this will provide the opportunity for another major advance in technology of the type which occurred at Broken Hill twice in the twentieth century. I wonder if our successors will look back at the 1990s and see a third great surge in metallurgical developments in Australia.

ACKNOWLEDGEMENTS

I am indebted to discussions with John Trezise, Bill Hardwick and Bill Davis about some of the events which occurred at Broken Hill during the 1980s and 1960s.

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Mining Heritage - What, Why and How?

G J Drew[1]

INTRODUCTION

Minerals are of course important to our way of living and hence the search and exploitation of minerals has always had a high priority in Australia. Metal mining commenced in South Australian in the 1840s when silver-lead and copper were first mined. This was *Australia's earliest mining era* and led to *the rush that never ended*. This and subsequent mining periods have had significant, widespread impact on local and national economic development, settlement, and social conditions.

Mining was our first primary industrial activity and therefore has a unique place in the development of Australia's economic social and cultural identity. Mining has also made an impact on the natural and built environments including settlement patterns and transport systems.

The widespread abundancy of minerals found and exploited within Australia during the last 150 years has left a significant array of industrial heritage items, which generally have distinctive characteristics. Today mining heritage forms an important and legitimate part of the nation's heritage. This heritage has been conserved mainly through neglect, and interpreted in a random way through various museums and interpretive centres such as Sovereign Hill.

WHAT IS MINING HERITAGE?

The Concise Oxford Dictionary defines heritage as *what is or may be inherited*. Put simply, this means that heritage is something that remains or has been passed on by previous generations.

Mining heritage is extensive and manifested in many ways. On one hand it is the tangible element associated with the physical environment of mines such as workings, buildings, relics, records, etc. On the other hand, mining heritage embodies human experiences, social customs and lifestyles associated with past mining. I will concentrate on the various physical remains and traces of mining activity that can be conserved.

Contemporary records

Records of mining company operations are generally large and varied, and include such things as annual reports, correspondence, working plans and photographs. For example records of the South Australian Mining Association include correspondence between the company secretary and the captain of the Burra Mine which provide a valuable insight into the operation of a 19th century mine, and details on machinery for the industrial archaeologist. Records of the Moonta and Wallaroo Mining and Smelting Co include a set of original water coloured mine plans dating from 1861. Such excellent collections are rare and usually only survive by chance. Will similar records exist for present mining operations in 100 years? Does it matter? Today some large companies have established their own archives, eg BHP, but records are generally transferred in random fashion to official archival collections.

Other historic records associated with mining activity are those compiled by government mines departments relating to inspections, leases, etc. For example, SADME has a complete set of original tenement plans and mining registers dating back to the 1850s, which form a unique part of South Australia's mining heritage. Generally adequate regulations exist for the preservation of important historical collections within government organisations.

Photographs and sketches of mining operations form another group of contemporary records, which are usually part of numerous official collections, where there are usually adequate conservation practices.

Although mining records are generally the domain of government departments, official archives, local library collection and museums, the mining industry should be move involved in preservation of its own records. Perhaps consideration could be given to assessment of records so that they do not disappear when companies cease operations.

Mining sites

Mining sites contain the physical evidence of mining and processing activity. This includes mine workings which may be underground or open cut, surface dumps, slag heaps, railway systems and surface structures. Structures may be associated with obvious mining activities such as pumping, winding and mineral processing, or for administration and housing of employees. Remaining relics range from small items such as picks etc to large boilers and engines.

Mining sites have a number of general characteristics which often create difficult and complex management decisions. These sites are usually remote and often very extensive due to the large scale of mining operations. In addition, such sites are stripped of any valuable machinery and materials soon after closure. Because of the nature of the industry, mine sites are frequently unattractive with large barren dumps, slag, derelict buildings, etc. This feature raises an interesting environmental conflict in conserving mine sites as the modern practice of rehabilitation may leave no legacy uf current mining practices.

The physical condition of mine sites can vary considerably from operating mines to ruinous sites, thus influencing significantly the conservation uptions available. Conservation of operating mines is not feasible due to continually changing technology and machinery. However it may be possible to combine tourist access with current mining operations, as is occasionally done, eg Leigh Creek coalfield, although potential liability seriously limits its application. A second group of mine sites are those which have ceased operating but are largely intact. These sites can range from mines which have only recently ceased operating and where the plant is relatively intact, eg Zinc Mine at Broken Hill, to deteriorating sites which have been closed for some time, eg Broken Hill South Mine. Cost of conservation and developmental operation of these sites in a relatively intact condition is very high. The third group of mine sites are those older sites which have deteriorated through neglect and natural decay to stable ruins. Old mining sites are most likely to survive in remote areas or on various reserves near populated ares, eg Nuccaleena Mine in the Flinders Ranges, and Burra and Moonta mines adjacent their associated towns.

Settlement patterns and transport networks

The physical evidence of mining also includes the infrastructure which supported the operation such as settlements and transport networks. This is particularly significant in Australia where

1. South Australian Department of Mines and Energy, PO Box 151, Eastwood SA 5063.

many mines are located in remote areas and have had a direct influence on the establishment of towns and transport systems. The mining of copper ores at Kapunda and Burra in South Australia in 1840 caused the first major decentralisation away from Adelaide. Land was surveyed for mineral tenements, mining townships and agricultural purposes, and basic road and rail networks were established during this period for cartage of ore and machinery. The effects of this early mining era on survey and settlement patterns can be clearly seen on present day plans and will remain long after the mining relics have disappeared.

The copper mines of Moonta and Wallaroo resulted in distinctive Cornish village-style settlements clustered around major focal points, such as churches, or mining leases. The lack of any regular geometry in the settlements contrasted strikingly with the rectilinear layout of nearby Government towns. What remains of the settlements at Moonta Mines is now protected within a State Heritage Area.

Mining communities

Mining settlements contain evidence which illustrates the lives of the people who were directly involved in mining activity. These settlements are part of mining heritage and just as important as the industrial remains which should not be isolated from the social context in which the mining operation took place. A good example of this is Burra's Paxton Square Cottages built as company housing in 1850 and in recent years conserved for tourist accommodation. One of the cottages has been retained in its original condition as a museum to interpret the social customs and lifestyle of a mining family. Other remaining buildings such as churches, schools, masonic lodges, etc, were part of the rich cultural, religious and political life in mining settlements.

WHY CONSERVE MINING HERITAGE?

Mining heritage represents a record of part of our cultural and technological history. Sufficient evidence must be kept to provide insights into the technical and human aspects of mining. This will allow present and future generations to learn from personal experience how much mining owes to human commitment and endeavour. It is vital that we pass on physical evidence of one kind or another to allow this personal experience. It has often been said that if you don't know where you have come from you don't know where you are going or, in other words, without a past there is no future.

Mining heritage provides the opportunity for a wide range of educational experiences for schools, tertiary institutions and the public. Mining sites can be developed for the appreciation and enlightenment of future generations. Such sites also offer, of course, the possibility of increased public awareness and respect for the mining industry, its processes and people, its history and heritage.

Mining heritage may be able to play an important role in cultural tourism. Tourism of course can contribute to the local economy and should be encouraged. Heritage conservation provides the visitor with authentic evidence and experiences of how former generations lived and worked. To be effective, visitors need controlled and interpretation must be provided to allow an understanding of the mining operations. This also applies to present mining operations which can generate tourist interest of their own.

HOW CAN WE CONSERVE MINING HERITAGE?

Having established the nature of mining heritage, what can we, indeed should we do about it?

Clearly it is not possible to conserve all mine sites so systematic assessment of sites should be undertaken to determine their relative significance, to decide on priorities for heritage listing and determine policies for conservation and management of various sites. Thus we must select sites which have special significance.

In Australia, recognition of the value of heritage conservation began in the 1950s with the emergence of the National Trust. Since the 1970s, each State has passed legislation to cover various areas of heritage. In South Australia documentation and assessment of individual sites is carried out by the State Heritage Branch which makes recommendations for sites to be added to the State Heritage Register. Criteria used in the assessment process include:

- historic and cultural significance — the site must have outstanding historical significance in a State or region;
- aesthetic value — some sites may contain dynamic features in the landscape, eg Worthing Mine enginehouse;
- distinctiveness — sites may contain items which are rare or even unique, eg Wheal Ellen Mine in South Australia contains the only known surviving arsenic labyrinth in Australia and would rank higher than say a number of remaining gold batteries which are relatively common in Australia;
- technological — a site may contribute to the understanding of the development of mining technology or to scientific research, eg ore dressing complex at the Burra Mine;
- intactness — the extent and physical condition of surviving heritage structures, eg Junction Mine at Broken Hill; and
- educational/tourism value — the suitability of the site for various interpretive purposes including the accessibility and proximity to population centre. The nature of land tenure is also important as it would be a better option to conserve a site on public land that can be managed by the controlling authority, rather than a similar site on private property.

Using these criteria, the SA Departments of Environment and Planning, and Mines and Energy produced a *Mining Systems Plan* in 1984, which has led to the conservation and interpretation of a number of ruinous sites by careful selection of priorities allowing limited resources to be used for the greatest overall benefit.

Once an effective identification and assessment system has been established, the next step is conservation of heritage sites. The Burra Charter (Australia ICOMOS) provides guidelines for conservation in Australia. It defines conservation as all the processes of looking after a place so as to retain its cultural significance. Briefly, conservation may include:

- preservation which maintains the fabric of a place in its existing state;
- restoration which means returning the existing fabric to a known earlier state without the introduction of new material;
- reconstruction which means returning a place as nearly as possible to a known earlier state by the introduction of materials; and
- adaption which modifies a place to suite a compatible use.

I have already suggested that there are three kinds of mining heritage; operating mines, non operating but largely intact sites, and ruinous sites. However conservation of operating mines cannot be considered for various technical and economic reasons. What action do we implement to enable conservation and development of suitable historic mine sites? I will consider several options ranging from total neglect to significant reconstructions.

The simplest and cheapest option is to do nothing and allow the site to naturally decay. For example, disused Cornish enginehouses have remained standing more than a century in many parts of the world and historic underground workings survive relatively intact at numerous localities, eg Glen Osmond. However, these have survived through good luck, and sound structural features or perhaps because of isolation. In South

Australia more structures survive from the earlier mining periods (1840 - 1890) than later activity because of the technology of the era. Substantial stone structures were erected to house massive pieces of mining machinery but later periods have seen the use of more portable machinery and prefabricated building material. While neglect may be acceptable for ruinous sites which have stabilised it presents problem for relatively newer mines where machinery still remains and hence vandalism and theft may be significant.

Another relatively simple option is conserve only a significant element when a mine site is abandoned as a symbol of previous mining activity. For example remaining headframes at Broken Hill could be retained and conserved as a symbol to the local community and visitors of the significance of mining and the line of lode.

A factor which may pose a significant threat to mining heritage sites is the renewal of mining operations because of the size and scale of modern open cut methods which are not compatible with the scale of historic operations. The possibility of conservation of such sites will depend largely on the economic value of the mineral resource in the mine area regardless of any heritage legislation. In such cases the only solution may be a detailed historical survey and documentation of the site, perhaps followed by relocation of any important relics. The removal of relics however must be seen as the last alternative as the historic significance is lost when moved. Two relatively recent open cut operations in historic mine areas provide good examples. At Burra, one of four remaining Cornish enginehouses was demolished and its chimney resited near the main road. As another near-identical enginehoue was left standing on the edge of the open cut, little technological information was lost. An historic wooden headframe at Broken Hill's Central Mine was removed to make way for open cut operations and resited in a prominent position near the Tourist Centre. It now forms a focal point and interpretive area for visitor embarking on Broken Hill heritage trails.

Clearly the best option where there is no threat of renewed mining activity to mining heritage sites is conservation of the site and/or historic structures *in situ*. Conservation of sites must always be facilitated by making use of them for some acceptable and compatible purpose. Historic structures can be conserved for some other industrial use, adapted for public or private use, as a museum or simply as a visual amenity. Generally intact mining structures are conserved mainly as museums using various government grants. Conservation of such structures usually involves restoration and reconstruction which is expensive requiring high standards of historical accuracy. This often cannot be justified on economic grounds because many mine sites are in remote locations where visitor numbers will not generate sufficient income. Conservation of intact sites is probably only economically viable where visitor numbers are large or heritage values exceptional. Such sites are probably near large mining towns, such as Broken Hill, where a significant tourism industry already exists. Examples include Delprats Mine at Broken Hill and the Central Deborah Mine at Bendigo.

For the majority of mining heritage sites, the only relatively economic and effective option is the conservation of ruins in their present state with minor restoration or construction of structures to provide focal points or visitor centres. For many sites it is possible to use the total mine area as both the setting and the main exhibit of the museum. Such sites can be developed as open air museums by developing conservation and interpretive plans that allow public access for recreation and/or educational purposes. Authentic interpretation can only be carried out by conservation of historic sites in situ. This method still poses some problems of protection, vandalism, etc but these can be largely controlled by careful planning of public access and visitor movements which in many cases is restricted to pedestrian access only.

Perhaps the best example in the world of the systematic development of an historic industrial site is the Ironbridge Gorge Museum in England. Ruins of various historic buildings are conserved as they are or as they were excavated such as the Coalbrookdale iron furnace. Others are adapted to use as museums such as the Museum of Iron and Coalport China Works Museum. In Cornwall the enginehouses at the famous Botallack and Levant Mines on cliffs overlooking the Atlantic Ocean have been conserved, including the restoration to working conditions of the Levant beam winding engine which was erected in 1840. Much of this work has been carried out by volunteers from the Trevithick Society. At present, a variety of Cornish organisations are sponsoring a major project to produce one of the finest and longest industrial heritage trails in the world. Known as the Mineral Tramways Project, the aim is to conserve numerous mine sites in the Camborne-Redruth area, provide visitor and interpretive facilities and link them by a network of trails based on old mineral tramways.

South Australia has an important and significant mining heritage which is being conserved and interpreted. The success of this work and the cultural tourism industry based upon it is due to a number of reasons including the accessible locations and aesthetic qualities of many of the historic mine sites, the permanence of many of the structures and buildings, protection by State heritage legislation and adequate documentation of sites. Since the early-1980s, a series of heritage drives have been established in the five major historic copper mining towns and a network of ten self-guided walking trails highlighted by the use of interpretive signs, has been established at a variety of historic mine sites. Conservation work has been undertaken at a number of sites, including Glen Osmond, Burra and Moonta, and several reconstruction and adaptions have been carried out for use as museums. The most notable has been the reconstruction of Morphetts Enginehouse and Shaft at Burra (see paper on the Burra Mine Museum). The total cost to date of these projects is probably of the order of $1 - 2 million. This must be balanced by estimated 100 000 visitors who visit these sites annually and the resultant economic benefits to South Australia's cultural tourism industry.

An alternative to the problems associated with conservation of historic mine sites is to recreate mining heritage at an appropriate location where maximum income can be derived from visitors, eg Sovereign Hill at Ballarat. Such sites it may be argued can play a role in eduction of the public and raising the level of awareness in conservation of authentic mine sites.

Although conservation of modern mines is not considered possible, another option is the identification of significant mine sites and structures well ahead of the time the mine ceases operation. Normally after closure mines are salvaged, buildings demolished, all portable items sold and the site and what remains is left to the elements. Perhaps several generations later an assessment is eventually made of the heritage significance of the now ruinous site. An obvious solution would be to assess the heritage significance of the site before mining ceases. If this type of assessment had been made when the Moonta and Wallaroo Mining Company closed in 1923, perhaps one Cornish beam engine may have been retained for future generations.

Clearly such an assessment can only be contemplated for very important sites where the future of mining is relatively clear. This is, of course, possible only if there is some economically viable use for the site. A good example of where this could be applied with help from the mining industry is at Broken Hill. Mining at Broken Hill has been carried on continuously for more than a century on the world's largest silver-lead-zinc orebody of such high grade. With the imminent closure of the last remaining mine within the next 20 years what will happen to the present surface structures which are clearly of world heritage significance? Although little survives of the earliest period of mining at the centre of the orebody, the surviving heritage is

typical of early modern mining machinery. These include headframes, winding engines and surface buildings ranging from 1900 to the 1940s, as well as underground workings at the North, Junction, South, Zinc and NBHC mines. Although on current mining leases, the South and Junction Mines have not been worked for many years, but fortunately surface plant is largely intact. Heritage assessments of these sites have recently been completed at the direction of the city council. The Zinc Mine closed in 1988 and North Mine will cease operations in 1993, leaving NBHC Mine as the only operating area.

Fortunately Broken Hill has an existing tourism industry based on its location and heritage which would be complemented by a world class mining museum situated at an appropriate location on the line of lode. Planning for this museum which should include an underground experience must start now. The mining industry could play a leading role in conservation and interpretation of its own heritage at Broken Hill to world standards. Assessment of the surviving heritage and support from the mining industry would allow decisions to be made about what structures should be conserved and how the sites can be managed. It may be too late in 20 years.

SUMMARY

The nature of mining heritage varies considerably and presents a wide range of conservation problems and options. Sound conservation policy must be based on prior assessment of mining sites. As it is not possible to conserve all sites, systematic assessment will determine which sites have special significance.

Conservations of sites is assisted by making use of them for some acceptable and economic purpose, usually as museums where income can be generated from visitors. In general, historic mine sites can be preserved in their present state and interpreted *in situ*. Retention of intact sites is usually uneconomic unless the heritage values are exceptional and/or visitor numbers large. Assessment of these sites should, if possible, be undertaken before mining ceases. Conservation of ruinous sites is probably the ouly economic method of protecting our mining heritage.

Mining heritage sites represent a record of our technological and cultural history and are tourism assets. Conservation of this heritage must involve present and future generations. Public awareness and education should generate sufficient public support for it to be achieved.

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BROKEN HILL CITY COUNCIL

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PLEASE ADDRESS ALL COMMUNICATIONS TO THE GENERAL MANAGER

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TELEPHONE/PERSONAL ENQUIRIES
ASK FOR Mr. P. Oldsen

October 16, 2000

P.N. Benkendorff
Engineering Heritage Committee
Sydney Division
6 Cadwells Road
KENTHURST NSW 2156

Dear Peter,

Centenary of Federation Plaquing

Reference is made to your recent correspondence dated August 28, 2000 regarding the above mentioned matter. You are advised that Council at its meeting held September 27, 2000 resolved to support the project and nominate either the Town Hall Façade, The Trades Hall, the Line of Lode or the TAFE Building as suitable sites.

Council wishes you every success with this particular project. Please contact the undersigned or Council's Heritage Officer, Mr. Brian Anderson to coordinate the project.

Yours faithfully,

P. OLDSEN
ACTING GENERAL MANAGER

Parliament of New South Wales,
Legislative Assembly

PETER L. BLACK, OAM, MP

Member for Murray Darling

September 26, 2000

Mr. P. Benkendorff
Benkeng Pty Ltd
PO Box 198
KENTHURST N.S.W. 2156

Subject: Centenary of Federation Plaquing Project

Dear Peter,

Thank you for your correspondence of September 12, subject as above.

At the outset, kindly permit me to express my great appreciation of your promotion of Broken Hill for the project. I note that the supporting documentation approximates that used by the U.K. Institute of Engineers in support of its award to Broken Hill in 1998.

Opportunity is taken to applaud your suggestion to use the front of the Argent Street TAFE (former Technical) College for the purpose.

Please be assured that any assistance which I might provide in progressing the project would be eagerly given.

Yours faithfully,

Peter L. Black

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Member, Australian IMM,
Member Australian Geological Society

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